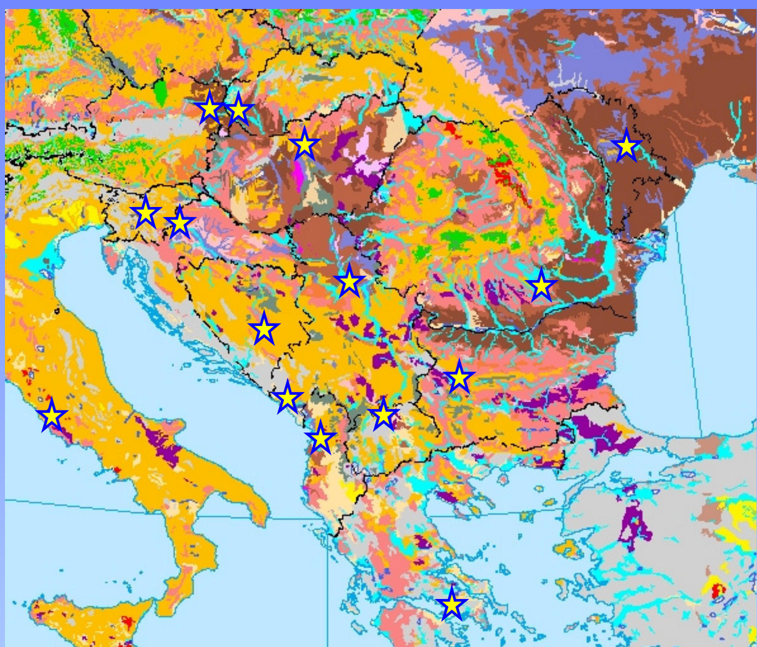
# Status and prospect of soil information in south-eastern Europe:

## soil databases, projects and applications

Edited by:
**Tomislav Hengl, Panos Panagos,**
**Arwyn Jones and Gergely Tóth**

**Institute for Environment and Sustainability**



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Institute for Environment and Sustainability

Contact information
Address: TP Box 280 JRC Via E. Fermi 1, 21020 ISPRA (VA) Italy
E-mail: tomislav.hengl@jrc.it
Tel.: +39-0332-785535
Fax: +39-0332-786394

http://eusoil.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu



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# I. The JRC Workshop on strengthening research networks in south-eastern Europe in support of soil protection policies

Panos Panagos, Arwyn Jones, Tomislav Hengl and Gergely Tóth

Land Management and Natural Hazards Unit
European Commission, Directorate General JRC, Institute for Environment and Sustainability, TP 280, Via E. Fermi 1, I-21020 Ispra (VA), Italy
Tel. + 39 0332 785574; Fax: + 39 0332 786394
panos.panagos@jrc.it; arwyn.jones@jrc.it;

**Summary**

*This chapter includes the minutes of the JRC workshop in Zagreb and some basic conclusions. The chapter is organized as follows. In the first part the background information of this meeting and the main points are presented. The first day of the meeting was dedicated to the overview of soil information in each of the Southern-Eastern European countries. In the related section, brief description of all presentations is listed. The second day has been divided into two sessions: the first session was dedicated to the European Soil Data Center and the second session was related to Digital Soil mapping. This report follows the same structure: first a review of activities is given for the countries in the region, followed by a review of the methodological development that can support soil protection policies.*

## I.1 Backgrounds

One of the key objectives of the JRC is to **support the uptake of scientific and technical aspects of European Union's (EU) legislation (the acquis communautaire) in New Member States, Acceding, Candidate and Potential Candidate Countries** and to promote Community strategies in countries within the area of the EU Neighbourhood Policy. An area of rapidly developing initiatives is the EU's Thematic Strategy for Soil Protection, officially adopted by the Commission on September 22nd 2006 [http://ec.europa.eu/environment/soil/]. The strategy makes a clear statement of the need for policy relevant soil information and indicators across Europe for the identification of areas at risk from a variety threats to soil function. In this context, the Land Management and Natural Hazards Unit of the JRC's Institute for Environment and Sustainability recently held a workshop with the specific objectives to strengthen collaboration on soil protection between the JRC and the countries of south-eastern Europe and to improve contacts between researchers and policymakers in the region.

The workshop, supported by the University of Zagreb and the Croatian Soil Science Society, brought together key players in the development of soil policy, soil survey, soil monitoring and soil information systems from Albania, Bosnia and Herzegovina, Bulgaria, Croatia, FYROM, Slovenia and Serbia and several neighbouring states (Greece, Hungary and Austria). From a historical perspective, the workshop proved to be the mechanism to bring together, for the first time since the break-up of Yugoslavia and the conflicts of the 1990s, both soil researchers and policy makers from all over south-eastern Europe. The workshop provided a stimulus to initiate regional integration and promoted a fruitful dialogue between countries. For the countries of the Ex-Yugoslavia, this was the first time that the soil researchers officially met in more than 15 years.

The workshop, organized under the **auspices of the JRC's 2006 Enlargement and Integration Action**[1], was an opportunity to assess the current state of soil protection measures and policy relevant soil information in each country and facilitate discussions on best practices in soil protection. In addition, a number of JRC initiatives such as the Danube Basin Soil Information System and a review of Digital Soil Mapping techniques were presented to the participants as examples of activities for future collaboration between the JRC and participating countries. The meeting outlined a strategy for enhanced collaboration in support of proposed legislation to protect the quality of soil in Europe through participation in the activities of the European Soil Bureau Network and by the production of this report.

In the conclusions of the workshop, the participants urged the JRC to support a similar event within two years time to asses the progress made during this period. Each sponsored participant has accepted a responsibility to produce a 4000-6000 pages report, following their presentation at the workshop and the feedback received from all participants. Further information on this meeting can be consulted through the JRC's Soil Portal at: [http://eusoils.jrc.it/esbn/esbn_zagreb/]. Regarding the dis-

[1] Information for EU New Members, Acceding, Candidate and Potential Candidate Countries and other non EU countries is available at [http://www.jrc.ec.europa.eu/enlargement/].

semination of knowledge and communication, the secretary of the workshop has prepared a list of participants and the "*Who is Who*" guide, which is also available via the Soil Portal.

**Fig. I.1: Group photo of ESBN workshop participants.**

## I.2 Day#1: Overview of soil information and soil protection

The workshop was opened by prof.dr. Pejić (Head of the office for international relations of the Faculty of Agriculture in Zagreb) who presented the mission, the history, the educational activities, the scientific research, the main achievements and the international cooperation programme of the Faculty of Agriculture in Zagreb. Prof.dr. Bašić (Faculty of Agriculture, Zagreb) further gave a talk entitled "Possibilities for cooperation in soil protection policies of south-eastern Europe". He mentioned how soil science has a long tradition in the southern-eastern part of Europe, especially in former Yugoslavia. He focused mostly in the problems after the recent war in the Balkans and emphasized the historical importance of this meeting. He pointed out that this meeting is the first time that soil scientists from ex-Yugoslavia have sit down around the same table after the break-up of Yugoslavia.

Mr. Panagos (JRC) presented the Soil Thematic Strategy and the Proposal for a future Directive COM(2006)232 of 22/09/2006. This was the first time that the proposed Directive was presented to the public and to various key players connected with the management of soils. Mr. Panagos reviewed the five soil threats, the annual cost of soil degradation and the next future steps after the adoption of the future directive. The JRC has an important role in the implementation of the Directive as it will be responsible for the establishment of the future European Soil Data Center (ESDAC).

Mr. Lushaj Sherif from the Center for Sustainable use and Management of Natural Resources in Tirana presented an overview of the soil information and soil protection in Albania. He focused on the Albanian Soil Classification system and its relation to the international one. Also, he underlined the contribution of the Soil Sciences Institute (SSI) of Albania to the implementation of the 1:1M European Soil Database. Land fragmentation seems to be a serious problem in Albania together with land degradation and soil erosion. Also, he mentioned the lack of national legislation regarding natural resources conservation and soil management.

Prof.dr. Čustović reported on the status of land resources in Bosnia & Herzegovina (B&H). Regarding the past projects, he presented the Project of the Basic Soil Map (BSM) which has been founded 1964 in the scale of 1:50,000 by Agropedology

Institute from Sarajevo. He also presented Inventory of Post-War situation of Land Resources in B&H. He underlined mostly the problem of mine-fields as the mines are still one of the main constraints to the development of the rural areas in B&H. Regarding the land consolidation problem, he underlined that land in B&H is too much fragmented and actions should be taken to deal with this problem. The lack of soil data seems to be a serious issue in this country.

Dr. Kercheva made an inventory of soil information coming from various soil surveys and a series of soil maps covering the whole territory of Bulgaria at various scales. At the moment, there are attempts to produce small scale regional maps (Digital soil map of Silistra region), but there is no national strategy on how to organize the soil information in the whole country. The colleagues from the N. Poushkarov Institute of Soil Science presented the National System for Environmental Monitoring Control. Finally, colleagues from Bulgaria presented the national legislation regarding environmental protection and various events (Conferences) devoted to soil protection.

Mrs. Mesić from Croatian Environmental Agency presented the Croatian Soil Information System (CROSIS) which is under development. CROSIS is part of the Environment Information System (EIS) which is based on distributed databases and GIS Technology. In the last few years, the Croatian Environmental Agency has developed the Corine Land Cover database and the Soil and Plant laboratory database. The principle objective in the coming years will be to harmonize the Croatian Soil Information System according to the principles of the European Soil Information System – EUSIS.

Dr. Cvetkovska reported on the status of the land use in the former Yugoslav Republic of Macedonia (FYROM) and underlined that the most crucial aspect of soil management in FYROM is the soil erosion. According to the European Environmental Agency report, FYROM is the red zone of erosion in Europe, especially due to the water erosion. Dr. Cvetovska further mentioned that the major problem of soil protection in FYROM is that it is regulated by several laws. One objective of the national authorities is to identify funding sources for reclamation of historical soil contaminations due to the operation of mines in eastern parts of the country. Another major activity will be the digitalisation of national soil map at scale of 1:50,000.

Dr. Theocharopoulos presented the latest developments regarding the soil data availability in Greece. Soil mapping in Greece is carried out by Nagref (Soil Science Institute), some universities specialized in this domain and the Ministry of Rural Development. Dr. Theocharopoulos described the soil information databases and the problems currently faced. He also identified the objective that soil data should be digitized and stored in global, user friendly GIS and linked to national and international bases. At the end, he listed the soil protection actions against the soil threats (erosion, nitrates, organic matter decline, contamination, compaction… and similar). He also proposed establishment of a National Harmonised Monitoring system, which could be organized at EU level.

Dr. Tóth presented the soil monitoring system in Hungary and the status of soil information resources. He reviewed in detail the Soil Monitoring System in Hungary, soil information sources, the soil evaluation system and the national legislation for soil protection. The progress done in Hungary is significant as major part of the 1:100,000 soil maps have been already entered into a GIS. There is an active soil monitoring scheme in Hungary, but it has problems with implementation. Also, there is plenty of soil information and maps at a detailed scale, but most of the field observations are old (>20 years). Dr. Tóth also made also an interesting live presentation of the mapping services provided on the web.

Mr. Sharku from Kosovo UNMIK presented some statistical soil data and the main issues of land damage which is divided in contamination, degradation and destruction. The main reasons for the land damage is the lack of laws, the incomplete strategy in environmental protection and the lack of information system for monitoring. The Ministry of Agriculture (MAFRD) has a plan for environmental protection but as Mr. Sharku mentioned the biggest problem is the lack of information on soil resources.

Mrs. Vidojević presented the short-term and medium-term soil policies and the soil monitoring schemes in Serbia (around 700,000 ha of unmapped soils). Her colleague from the Faculty of Agriculture in Novi Sad, Dr. Manojlović, described the Soil information systems and the progress in digitizing soil maps. A promising output was the soil map of Vojvodina, based on classical map in a scale of 1:50,000. Both colleagues listed the lack of a permanent monitoring system, the need for a GIS integrated software system and the national soil taxonomic system (not complaint with WRB), as the main problems of the soil monitoring strategies in Serbia.

Mrs. Krsnik presented the soil legislation and the National Environmental Action Plan in Slovenia. The data collection is done by the National Environmental Agency and the Slovenian Soil database is under development but reports and maps are available upon request. The Colleagues from Slovenia have also identified the need for a harmonised soil monitoring system to be established in order to record the state of soil pollution at national and EU level.

During all of presentations, fruitful discussions took also place regarding the variety of soil information in South-Eastern Europe. These reports will be used to update the ESBN Research Report No 9 "*Soil Resources of Europe*". The information related to each of the Southern-East European countries will be updated with new contents provided by the contributors on a regular basis.

# I.3 Day#2: Soil Data Centre and Digital Soil Mapping

The second day was split into two sessions. The first one focused on the organization of "European Soil Data Centre" and ways to integrate also the countries in the region in these activities. The second session was entitled "Digital Soil Mapping" and focused on the development of new tools that can be used to produce more accurate and more usable soil information.

### *I.3.1 Soil Data Centre Session*

During the first session Dr. Houskova (JRC) presented the Flood Risk Assessment project and the current status in the Danube basin soil database describing also the data management procedures. She analysed the database structure and presented in detail the technical requirements of this project. This workshop was an opportunity to meet those data providers who have been present on the meeting and to proceed with the countries which haven't still contributed their national datasets.

Mr. Panagos presented the European Soil Portal and the current developments taking place in the European Soil Data Center. He has presented the various sections of the European soil Portal and underlined the importance of national and regional data-sets. In addition, Mr. Panagos presented the future structure of the European Soil Data Center and how the data coming from national or regional data centers will be integrated into this virtual world.

Dr. Hannam (University of Cranfield) reported on the activities connected with the SPADE 2 (Soil Profile Analytical Data-base for Europe) project. "SPADE 2" will be extended as the objective is to expand the 'estimated' soil profile database to include 'primary' soil properties for all STU's. Moreover, additional countries are invited to contribute to this project and communication has been established for 12 countries in Balkans, Southern East Europe and Baltic states. The current meeting was an opportunity for the project co-coordinator to meet data contributors from South-East Europe and to resolve the pending issues.

Dr. Tóth (JRC) presented the European perspective on soil quality. Participants of the workshop showed interest towards this issue and proposed collaboration for applied research. Dr. Tóth presented the soil quality indicator and the soil functions. Also, he described the approaches to risk area identification and risk characterization (the so-called *two TIERS concept*). The analysis was based on the five threats described of the proposed European Soil Framework Directive.

Dr. Zdruli (Mediterranean Agronomic Institute of Bari, Italy) has presented a hot topic related to monitoring of land degrada-tion. He underlined the main factors which affect the land degradation both in Mediterranean and in the Balkans and he pre-sented the main methodologies for monitoring of land degradation. He concluded that the combination of expert-based as-sessments with remote sensing tools is needed in order to ensure successful monitoring systems.

### *I.3.2 Digital Soil Mapping (DSM) session*

During the second session, technical presentations regarding the Digital Soil mapping have been followed. Dr. Hengl (JRC) opened the session by reporting on the DSM activities related with the Danube basin Soil Information System. Dr. Hengl started by explaining basic principles of the key technique used to map soil variables – regression-kriging. At the moment, the DSM group is in the phase of preparing the GIS layers (DEM-based and MODIS-based predictors, soil variables). The first outputs are expected within June 2007, when the version 0.1 of the Soil Information System at resolutions of 250 m and 1000 m will be launched. This would then be a good occasion to organize a similar workshop to present the results from the project and receive some feedback from the users' community.

Mrs. Martina Baučić, from the Geodata company in Split, further reviewed the state-of-the-art in topographic data sources (aerial photos, topographic maps, LIDAR images and similar) and emphasised their added value for DSM applications. Mrs. Baučić described topographic data acquisition methods (land surveying, Global Positioning System – GPS, photogrammetry) and the various topographic datasets available in Croatia. One line of her presentation was marked by all: "*A fairly accurate GPS can be today bought for a price less then 1000 € − today, everybody can be a mapper*".

Two colleagues from University of Gottingen in Germany, Dr. Ringeler and Mr. Bock, further presented some collaborative work connected with the SAGA GIS development team and DSM applications. The SAGA GIS group had advanced ideas on how to use DEMs in a semi-automated way. However, at the time the market was not ready to accept the development of DSM applications. Today, the situation seems to be more promising. Dr. Ringeler explained the group's DSM framework and illustrated the procedures using several case studies from Germany. The most novel element of the SAGA Development team approach to DSM was representation of soil forming processes. This is a refinement of the standard DSM techniques that lays a basis for more sophisticated approaches to DSM. The SAGA GIS has shown to be quite suitable for the DSM applications because it is an open-source package with popular interface and especially suited for mapping (interpolation) projects.

In the second block of the DSM session, Dr. Vrščaj Borut from the Agricultural Institute of Slovenia presented the available soil information in Slovenia and gave a review on the Institute's activities related with DSM applications. Dr. Vrščaj pre-sented how the DSM spatial tools may be used to improve the soil information for soil protection and soil quality management on the local level. Part of his presentation was dedicated to expert knowledge DSM examples. Again, DEMs and its derivatives have shown to be especially useful for improving both thematic and spatial detail of the traditional soil maps.

Dr. Marija Romić, from the hosting institution, demonstrated how geostatistics can be used to map heavy metals measured in soil. Such soil monitoring projects will have more application in the near future. Mrs. Freudenschuss from the Umweltbundesamt in Vienna further gave a review of Legislation in Soil Protection and presented the soil mapping and monitoring activities in Austria. Mrs. Freudenschuss presented also the Soil Information System BORIS and the available data sets in this system. The Umweltbundesamt is invlolved in th development of a metadata base to existing Forest Site Mapping (Meta Map-BFW), implements interpolation of point related soil data and contributes to the development of soil indicators (national & EU level). Mr. Klaić from the Institute for Soil in Osijek next reported on the mapping activities of this organization in Eastern Slavonia.

The last presenter, Dr. Mukaetov from Institute of Agriculture in Skopje closed the session with his review of various GIS projects in Former Yugoslavia Republic of Macedonia which are connected with the mapping and monitoring of natural resources. He specifically mentioned numerous constraints (lack of professional personnel, unclear data sharing policies etc) that limit the real applications of GIS tools in everyday life. Dr. Mukaetov concluded with the need for intensive development of GIS and Remote Sensing application soil and water management and the future establishment of soil and water information systems. Dr. Hengl and Mr. Panagos finally concluded the workshop and opened a discussion panel.

## I.4 Conclusions

One of major goals of the workshop was to strengthen the collaboration on soil protection issues between the JRC and the countries of South-Eastern Europe and to improve contacts between researchers and policy-makers in the region. In summary, we can say that the workshop has reached this objective. This workshop also had a symbolic importance because it was the first time that representatives of the countries of ex-Yugoslavia had met after the break-up of Yugoslavia. The most important output of this workshop is this special Report. It will serve as a basis to prepare the updated version of the Research Report No 9 "*Soil Resources of Europe*".

The workshop promoted the information exchange between countries at one hand, and collaboration between the European Soil Bureau Network (ESBN) and the various key players that can be informed about the results, data, reports, etc. The JRC and further the European Soil Bureau Network supports these initiatives which also strengthen the relationships between various partners. In the context of the European Soil Bureau Network, active key players have been identified in this workshop and they have been proposed for the European Soil Bureau Network Steering Committee meeting to renew the representatives in some countries (example: Serbia).

During the first day session, an inventory of the current status in soil data in South-Eastern Europe has been done and individual contacts between JRC and various data holders will follow in order to identify better those National or Regional soil datasets. The JRC enlargement programme was presented briefly with the summer school activities and the workshop participants have shown an interest to be informed about the next event.

There were many important issues raised during the workshop and which have been also addressed to the European Soil Bureau Network Steering Committee. Which countries may be included in the next workshop related to South-Eastern Europe? Representatives from Turkey, Moldova and Romania have been invited to assist in the workshop but they could not attend the meeting due to various technical problems. The proposal for an Association of Mediterranean Soil Society is an initiative which concerns the members of various Soil Societies in Mediterranean countries and not the JRC. Dr. Zdruli also proposed the implementation of Soil Atlas of the Mediterranean and the establishment of a Mediterranean Soil Museum (Malta has been proposed). Also the initiative of a dedicated Summer School for issues affecting soil in the Mediterranean has been proposed. Because most of the countries in South-Eastern Europe are not members of the European Union, those initiatives cannot be financed by a specific budget in the JRC, but maybe a finance schema can be proposed to DG Enlargement or DG External Relations.

We identified that a large number of soil data in South-Eastern European countries have been collected but not digitized. A framework contract or another financing schema may contribute to those data collection exercises. In the next version of PESERA (**P**an-**E**uropean **S**oil **E**rosion **R**isk **A**ssessment), the South-Eastern European countries will be included. The colleagues from Albania have proposed the distribution of a questionnaire-like document in which Soil data holders will indicate what kind of data they hold(Soil profiles, Topographic data, etc), in which scale and when the data have been collected.

## Acknowledgements

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European Soil Portal Reference to the Workshop: [http://eusoils.jrc.it/esbn/esbn_zagreb/]

Soil Thematic Strategy: [http://ec.europa.eu/environment/soil/]

European Commission Enlargement actions: [http://ec.europa.eu/enlargement/]

# II. Land and soil resources of Albania: current problems and future trends

Sherif Lushaj[1] and Pandi Zdruli[2]

1 Center for Sustainable use and Management of Natural Resources,
Rruga "Ded Gjon Luli" Pallati 1, Shkalla 1, Apartamenti 17, Tirana, Albania
Tel: +355-4-227 985; Fax: +355-4-227985; blushaj@albnet.net
2 CIHEAM-Mediterranean Agronomic Institute,
Via Ceglie 9, 70010 Valenzano, Bari, Italy
Tel: +39-080-4606 253; Fax: +39-080-4606 274; pandi@iamb.it

**Summary**

*The profound political and economic changes of sixteen years ago brought unimaginable challenges to the overall economy of Albania and most importantly to the agriculture sector, which according to 2005 data provides about 25% of the Gross Domestic Product (GDP) and still remains an important sector of the country's economy. About fifty percent of the population yet lives in the rural areas. This figure in the 1990s was around 66%. During 1998-2004, the growth of agricultural production has been positive with annual increasing rates ranging from 5 to 8%. Numerous issues are at stake, however the sustainable use and management of natural resources remains a priority. Only 24% of the country's territory is suitable for cultivation and for worst, extensive areas of arable lands are under extreme threats of erosion, landslides, salinization, flooding, sealing, and soil fertility and organic matter reduction. Extensive soil survey programmes were implemented in the past, but they are reduced drastically and at present discontinued. The country possesses enormous information on soils, but very often this is scattered and difficult to reach. Efforts were made a decade ago to update the knowledge on soils following cooperation with USDA Natural Resources Conservation Service and the Albania's Soil Science Institute. Important steps were reached in the early 2000 through collaboration between the European Commission's Joint Research Centre (JRC), the Region of Apulia, Italy and the Soil Science Institute of Albania with funding provided by the Interreg II Italy Albania Project. It is most auspicial that such collaboration, especially with JRC being strengthened particularly in the context of further involvement of the European Commission in the Western Balkans region.*

## II.1 Introduction

The Republic of Albania is located in the Balkan Peninsula, between 39°38' and 42°39' N latitude and 19°16' and 21°40' E longitude. The overall country's territory of 2,874,800 ha, includes 699,500 ha of agricultural land (24.4%), 1,062,770 ha of forests (36.9%), 414,517 ha of pastures and meadows (14.4%), and 699,013 ha (24.3%) of other land uses, such as urban and barren land, water bodies, etc. The agricultural land surface area per person is about 0.21 ha. Albania is a mountainous country and only 16% of its territory is located at elevations of less than 100 m above sea level. Consequently, slope is a determining factor for Albanian agriculture. The agricultural land is distributed as follows: 43.3% located in the western plains or internal flat areas, 34% in the hilly zones; and the remaining 27.7% occur in the mountainous regions.

## II.2 Land Tenure and Agrarian Reform

Only 13% of agricultural land before 1945 was stately owned, whilst private individuals owned the residual 77%. The agrarian reform that was launched by the Communist Government in 1946 soon after the Second World War confiscated agricultural land and distributed it to thousands of landless families. The process was expanded all over the country. Simultaneously, during the period 1946-1968 the collectivisation of agriculture was started and completed creating a new form of land distribution with 21% given to newly-created state farms and the rest (79%) to "voluntarily established" agricultural cooperatives. The total country's agriculture land of around 700,000 hectares was given in use to 77 state farms (average 2,700 ha per farm) and 415 agricultural cooperatives (averaging 1,300 ha per cooperative). During this historical period, land (as any other type of asset) was proclaimed state owned property.

With the dawn of political changes in the 90's and the turn of the country to the free market economy, agricultural land was again privatised. During the period 1990-2004 around 564,000 ha or 98.9% of the arable land planned for redistribution and privatisation was freely given to about 450,000 farmer families. There are still many controversies on the way this privatisation was implemented (privatization is still on going). According to recent statistical data, the average farm size is about 1.3 ha making thus difficult to increase their productivity and to achieve farm modernisation. Forests by large still remain stately owned (73%) followed by 26% owned by the Communes (administrative units) while the private sector owns only 1%.

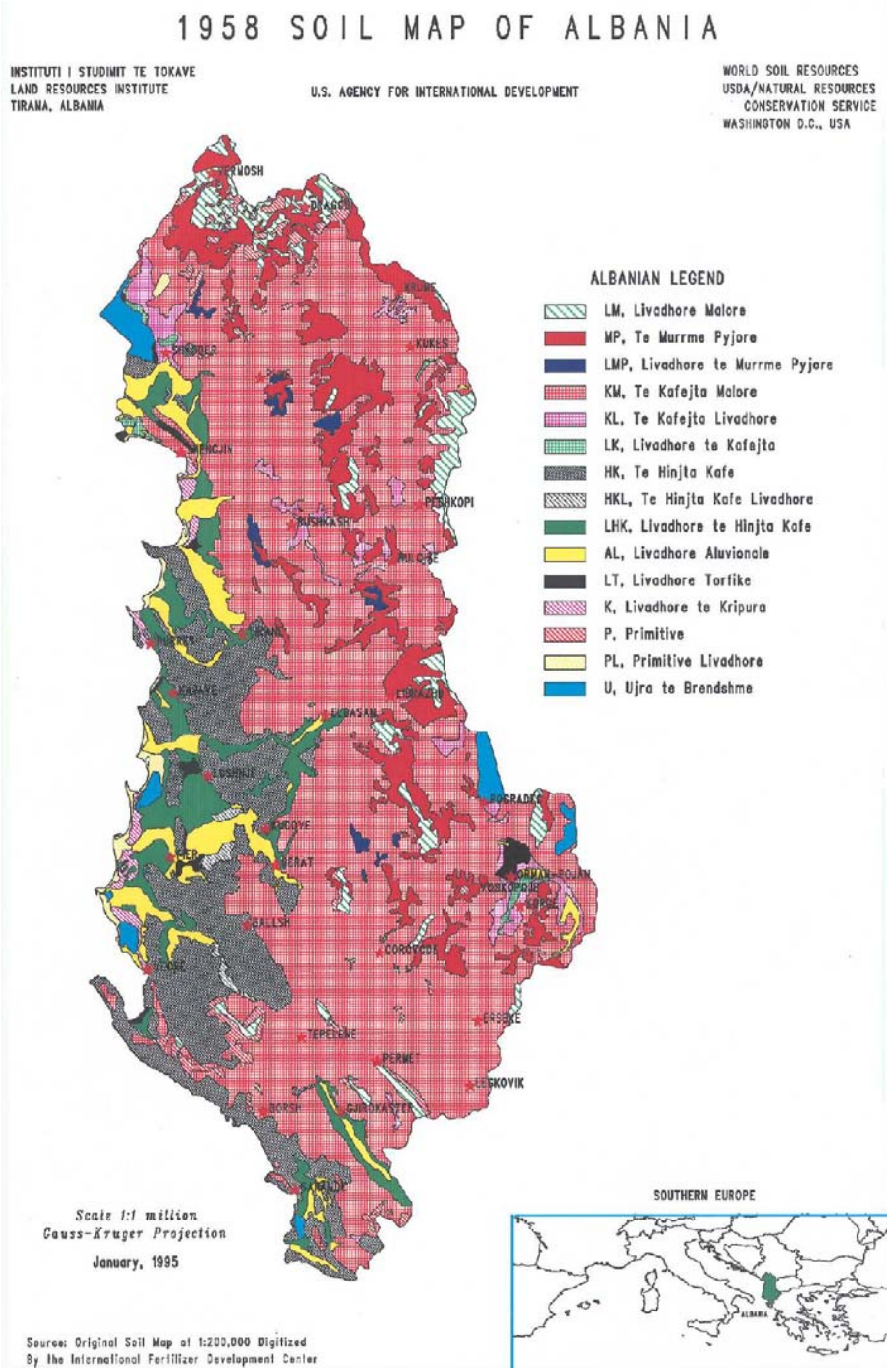



**Fig. II.1. The first soil map of Albania produced in 1958.**

## II.3 Soil Mapping and Soil Classification

Soil mapping and classification has a relatively long history in Albania with the first soil maps dating back in the late 1930s. The Agricultural University of Tirana was the pioneer of soil-based research and prepared the first soil map of the country at scale 1:200,000 (Fig. II.1). Veshi and Spaho, (1988) described the soil mapping units. Intensive soil surveys were conducted especially during the period 1971-1991, when detailed soil maps ranging from scales 1:10,000 to 1:50,000 were prepared for the whole agricultural land of the country (about 700,000 ha). Additional soil surveys were conducted to cover also pastures and forests. There are good reasons to believe that soil protection was considered an important aspect of land management and maintaining soil productivity was part of the political agenda.

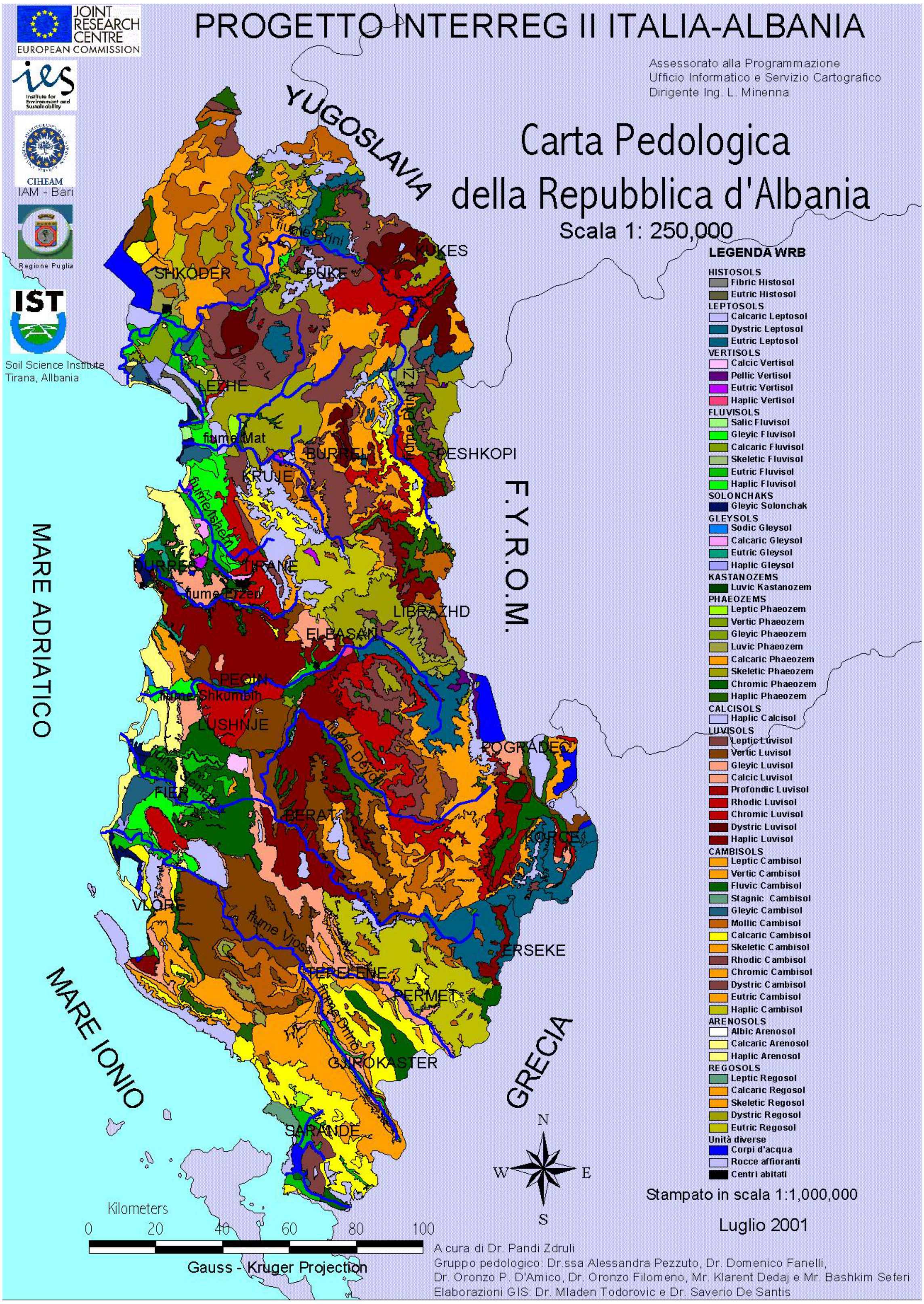



**Fig. II.2. Soil map of Albania according to WRB 1998 classification system.**

The long political isolation of the country had its toll also in soil science development and especially in soil classification. First orientations in developing a national soil classification system were derived from the Russian system, but in itself the Albanian system was a "homemade approach" that reflected mostly differences in soil forming factors with relief and vegetation being the most prominent ones. Due to the size of the country and particularly, to the extent of arable land, the Albanian soil classification system served its purpose, provided the first assessment of land resources and helped especially to make the appropriate decisions for instance on fertiliser use and land reclamation projects.

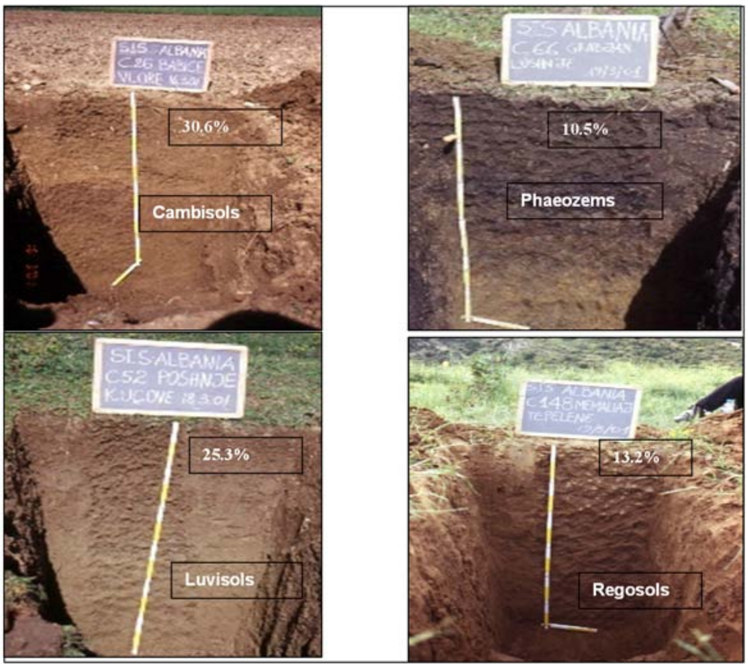



**Fig. II.3. Representative profiles of major soils of Albania.**

Modern soil science concepts such as and the FAO Legend (FAO-UNESCO, 1974), World Reference Base for Soil Resources (FAO, ISRIC and ISSS 1998) or WRB (2006), and USDA Soil Taxonomy (Soil Survey Staff, 2006) and previous editions, were introduced in Albania only after the political change of the early nineties. After the political change the soil survey and mapping was reduced drastically. The surveys being made by the Soil Science Institute were reduced to minimum. At present (end of 2006) soil mapping role of the Soil Science Institute has been restructured again with other looses in its functions. To re-invert the situation in the mid 1990s, the United States Agency for International Development (USAID) sponsored a national soil resources assessment inventory (Zdruli, 1997). This brought to the publication of the first soil map of Albania prepared according to an internationally well-known system. Zdruli (1997) provides the following soil orders according to the USDA Soil Taxonomy and the respective areas they cover in Albania (Table II.1).

**Table II.1. Classification of the soils of Albania according to USDA Soil Taxonomy.**

| *Soil Taxonomy orders* | *ha* | *%* |
|---|---:|---:|
| Histosols | 3,978 | 0.5 |
| Vertisols | 58,542 | 2.0 |
| Mollisols | 208,402 | 7.0 |
| Alfisols | 498,670 | 17.0 |
| Inceptisols | 1,015,951 | 35.0 |
| Entisols | 164,613 | 6.0 |
| Miscellaneous | 924,644 | 32.5 |
| Total land and water area | 2,874,800 | 100 |

Another great achievement was reached in 1998 when for the first time an Albanian soil database was introduced into the Soil Geographic Database of Europe at scale 1:1,000,000 sponsored by the European Commission (EC) Joint Research Centre, European Soil Bureau. This was followed in 2001 by a more detailed soil survey funded by the EC and the Italian Government aiming at the creation of a national soil database of the country at 1:250,000 scale (Fig. II.2) prepared according to WRB 1998 system and another much more detailed soil database for the coastal areas of the country at scale 1:50,000 (Zdruli *et al.*, 2003). The European Soil Bureau (ESB) was the technical coordinator of this project that was jointly implemented by the

Mediterranean Agronomic Institute of Bari, Italy and the Soil Science Institute of Tirana, in Albania. This brought a great advancement in soil surveys and put the country at a high European standard, being one of the few in Europe in 2001 to have completed a national soil database according to the 'Georeferenced Soil Database for Europe' Manual of Procedures-Version 1.1 (EUR 18092 EN, 1998) otherwise known as the ESB Manual.

This second major study (Zdruli *et al.*, 2003) conducted in 2001 revealed the distribution of soils according to the WRB (Fig. II.2). The Albanian pedological landscape is very diverse and complex. The lower coastal area of the western part of the country was mainly formed during the Quaternary period by the fluvial activity of several rivers flowing into the Adriatic and Ionian Seas. The dominant soils are Cambisols, Luvisols, Fluvisols, and Phaeozems, associated with Vertisols, Solonchaks, Gleysols, Arenosols, Histosols and Calcisols (see Fig. II.3).

On the eastern side of the coastal flatlands extends the hilly area covered by Mediterranean shrubs typically *Macchia Mediterranea* and cultivation of olive groves, vineyards, and fruit trees. Soils are moderately deep, but highly eroded and mismanaged, particularly by overgrazing. Luvisols, Cambisols, and Calcisols cover the largest areas. Mountains are spread throughout Albania from the Alps in the north to the central and southern areas. They are covered with pine, beech, and oak forests at lower parts while the highest elevations are mainly just bare rock. Above 2,000 m a.s.l. alpine meadows occur.

## II.4 Soil fertility trends and management

Until 1990, soil fertility was monitored throughout agricultural land every 4-5 years. Representative soil samples were taken for every 10 ha in the flat areas and for every 3-5 ha in the hilly and mountainous regions. This monitoring system along with a wide range of experimental trials assisted to establish appropriate soil fertility and plant nutrition management plans. Table II.2 provides soil fertility information in regard to the content of humus[2], total N, available P and K in the country's arable lands. The maps below show graphically the distribution levels of humus and phosphorus content according to major administrative units (i.e. districts) of the country.

Data show that 44.6% of the soils are classified as low in humus content (<1.5%). They are located mainly in the hilly and mountainous area and partly in the western flat regions. Additionally, 78% of soils are classified as low and medium in total N content, 75% are low and medium in P and more than 90% are medium to high in K. Until 1990, about 400,000 metric tons of chemical fertilizers or 150-160 kg/ha of active matter (NPK) were used annually. In addition, around 5-6 million tons of organic manure or 8-tons/ha/per year was added to arable lands countrywide. These amounts were sufficient to provide relatively high yields for major crops. The natural fertility of some soils, the climate, as well as advanced technologies played an important role in supporting good yields. Moreover, on the country's western plains considered as "the grain basket" of Albania, and in the areas where the yields were always higher than country's average, there was an excessive use of inputs and chemical fertilizers in particular.

**Table II.2. Soil Fertility level.**

| No | Level | Humus (%) | | Total Nitrogen (mg kg-1) | | Available P (mg 100 g-1) | | Available K (mg 100 g-1) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Arable land (%) | Range | Arable land (%) | Range | Arable land (%) | Range | Arable land (%) | Range |
| 1. | Low | 44.6 | <1.5 | 36.9 | 1.00 | 33.0 | 1 | 8.2 | <8.0 |
| 2. | Medium | 45.6 | 1.5-3 | 41.9 | 1.01-1.50 | 41.6 | 1-2 | 43.7 | 8.1-15 |
| 3. | High | 9.8 | >3 | 21.2 | >1.50 | 25.4 | >2 | 48.1 | >15 |
| | Total | 100.0 | | 100.0 | | 100.0 | | 100.0 | |

Until 1990 the fertiliser strategy was based on the principle of "*what was taken out from crops should be replaced by fertilisers, both chemical and/or organic*". The strategy therefore intended to maintain a positive nutrient balance in the soil. The results of thirty-five years of experience and research in soil fertility and plant nutrition in Albania indicate that the needs for nutrients, including nitrogen, phosphorus, and potassium varies depending on soil quality, types of crops, chemical/physical soil properties, expected yields, fertilizer efficiency, type of technology, and overall soil management.

[2] Humus is analysed using the Turin method. To determine Organic Carbon in soil, this value needs to be multiplied by 0.58. N – Kjehdal. $P_2O_5$ – Machigin, to convert to Olsen multiply by 1.5. $K_2O$ – Peyva.

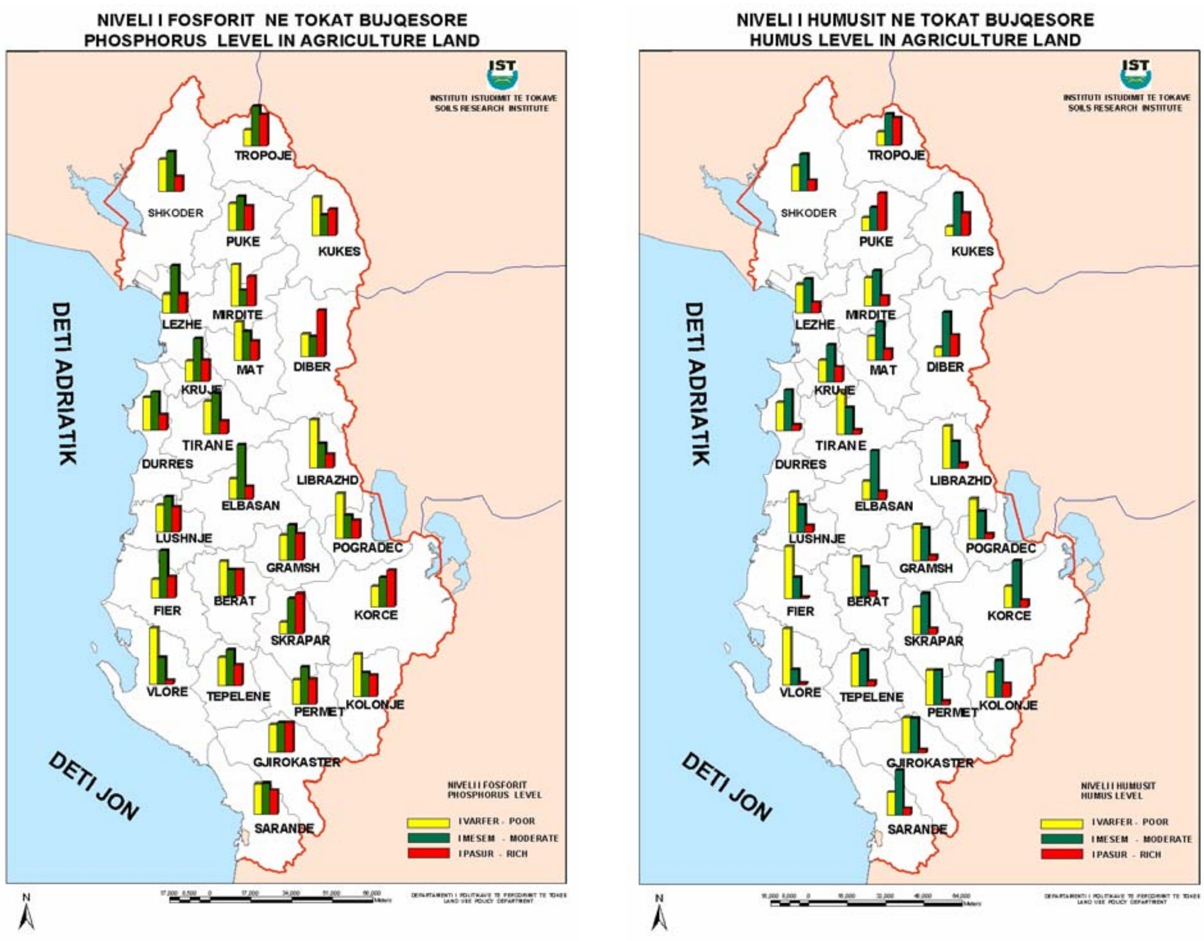



**Fig. II.4. Phosphorus (left) and humus (right) levels in the soils of Albania.**

Some of the most important findings of element-balance monitoring system, executed during the centralised economy era, showed that: (a) nutrition balance in the soil was positive, and (b) high amounts of nutrition elements were applied. However, they were accomplished by supplementary technology, only in the function of ever-increasing yields with no regard to environmental pollution. Finally, (c) fertiliser use efficiency was low.

During the transition period to free market economy, the soil fertility trends took a negative direction, pointing at a marked decrease of nutrient content in the soil bringing to a "*nutrient mining process*" in the flat lands and increased erosion and nutrient leaching in the hilly and mountainous regions. This is due to the fact that amounts of chemical fertilisers that are being used are in an average range of 70-80 kg/ha of NPK active matter (compared to 150-160 kg/ha NPK used until 1990), and only 20% of the amount of organic manure that was used until 1990 is being applied. On the other hand, in limited areas of the coastal zone, the quantities of both chemical and organic fertilisers used are so high that are causing surface and ground water pollution. There are also about 100,000 ha of agriculture land, which represent about 15% of the total arable land area that are abandoned and mostly overgrazed, hence causing further soil degradation.

## II.5 Land Use

Up to 1990, cropland utilisation was dominated by cereals such as wheat, maize, and barley that altogether occupied about 48.6% of the total agriculture land, followed by vegetables with 4.7%, industrial crops (cotton, tobacco, sunflower, sugar beet, and soybean) with 13.6%, forage crops with 23.5%, and beans and potatoes covering the remaining 6%. Fruit trees, olive groves, and vineyards, occupied 17% of the total agriculture land area (Fig. II.5).

After 1990, crop production structure suffered essential cultivation changes: cereals were reduced twice, while cotton, rice and sugar beet were totally taken off from crop production structure. The area cultivated with tobacco, sunflower and soybean was reduced (between 2 to7 times) due to lack of processing industry, poor opportunities for exports and low economic interest from the farmers. After 1990, land use and the structure of crop production have changed in favour of market-oriented crops. Alfalfa cultivation has also expanded substantially.

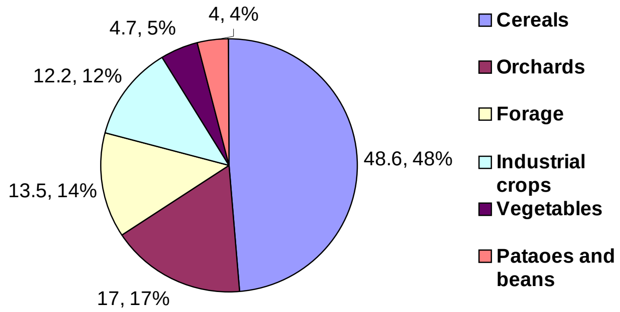



**Fig. II.5. Structure of Crops before 1990.**

**Fig. II.6. Land fragmentation in the valley of Prrenjas, Librazhd, south-eastern Albania**

Agriculture land area cultivated with forage crops, vegetables, beans, potatoes and vineyards has been increasing. This change in crop production structure is associated with forecasting of new balances of nutrition elements in the function of the expected yield, product quality and cost/effectiveness ratio.

These changes in land use were reflected in the soil fertility status. They are related also to new socio economic situation created in the country with the change of the political system. Due to population migration from rural to urban areas as well as immigration, over 40% of agriculture land was not cultivated for years in succession since 1990. Irrigation and drainage systems were almost unfunctional, while land degradation (including soil erosion, salinization, flooding, overgrazing, land abandonment, and sealing/urbanization) has drastically accelerated.

Another problem is land fragmentation. Due to the land privatisation process, small plots (parcels) were created which increased number of highly fragmented agricultural land. As of March 2005, the following statistics applies in Albania:

- 58% of total number of farms amount up to 1 ha in size,
- 30% of farms amount between 1-2 ha, and,
- 12% of farms amount over 2 ha in size.

The application of diverse crop cultivation practices by farmers under the conditions of massive fragmentation (Fig. II.6) as well as the differences in chemical or organic fertilizers application by each farmer has further worsened differences in soil fertility distribution even among adjacent parcels. The Albanian Government considers land consolidation as a strategic priority that should lead to the development of a land market based on land exchange, land suitability and quality, enhanced cooperation between farmers, and other consolidation forms. A remedy to the problem could be a well-thought agricultural land use planning policy that would consider crops as unifying instrument of land consolidation. Similar land property ownership patterns with Albania exist also in Greece and southern Italy for instance. However, land fragmentation in those countries is not as visible due to the fact that large areas are being cultivated with one (or few similar) crops.

**Fig. II.7. New plantation of olive groves in the hills of Central Albania.**

These forms facilitate application of modern technologies, especially in irrigation. Thus, when consolidation through land trading market mechanisms becomes difficult to implement, ecological and environmentally friendly land use options needs to be explored (as illustrated in the Fig. II.7 taken in Central Albania near Lushnje).

## II.6 Land Evaluation and Soil Suitability

At the end the 1990s, a physical land evaluation study was completed. Ironically, the study is an interesting unique case, since it was started under the centrally controlled political system (never applied because the collapse of the system itself!) but was used to solve problems related to land privatisation and distribution, land taxation, restitution and compensation of former land owners, that were never foreseen as objectives of such a study. The arable land was divided into ten suitability classes. Fig. II.8 provides a complete picture of the percentage surface area covered by each class. The first category is the best and the tenth the worst. As a general rule, while moving from West to East, soil quality is reduced due to harsher climate, increasing slope and elevation (Kaleshi *et al.*, 1992).

Coastal areas, which occupy about 250,000 ha, were classified as the best classes. Overall, soils included in classes I to IV occupy 46.0% of the total arable lands, followed by classes V-VIII with 43% and classes IX-X occupy the remaining 11% of the area.

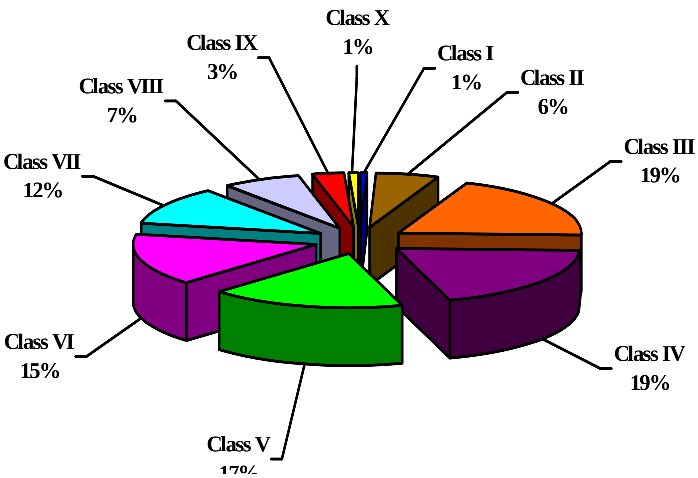
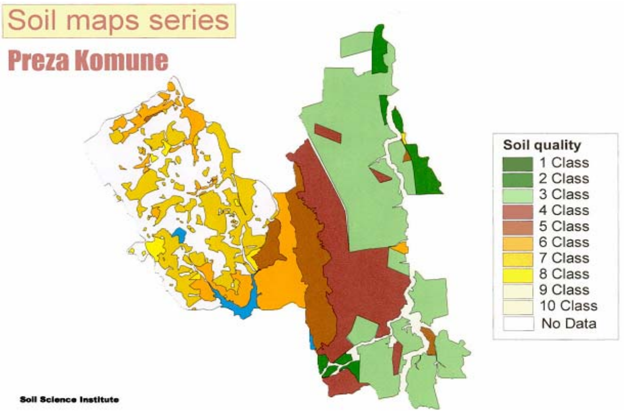
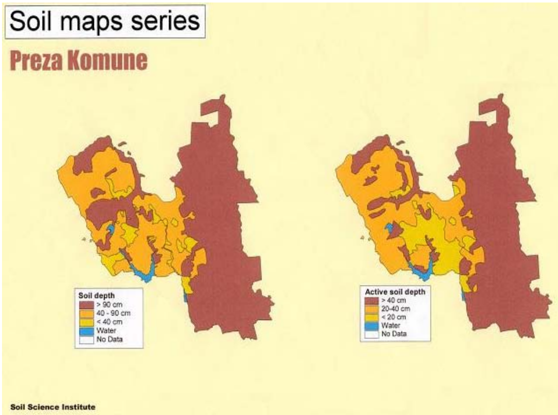


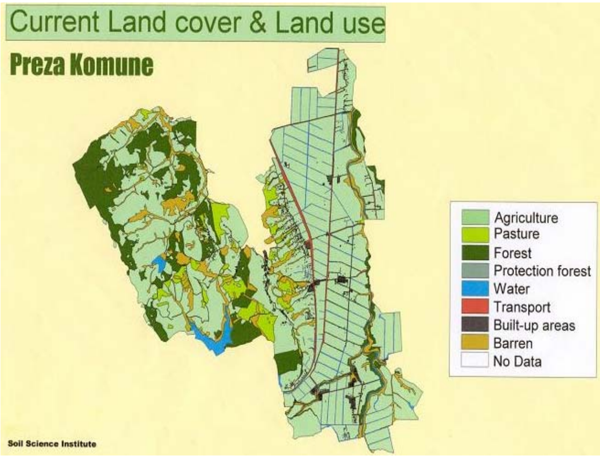

**Fig. II.8. Land Evaluation classes and their respective areas (in %).**



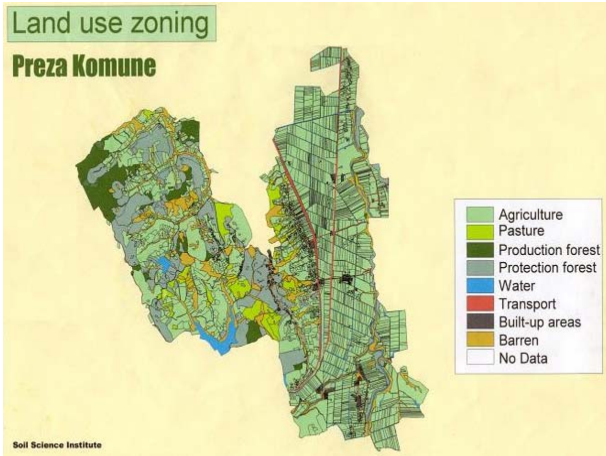

Soil quality classes of Preza Commune




Active soil depth of Preza soils (in cm)




Existing land cover and land use for Preza




Potential land use planning for Preza

**Fig. II.9. Some examples of soil mapping and land use planning projects in Albania.**

A first attempt to prepare maps for actual land use and potential land use planning was done by Zdruli (1997). He reports the distribution of arable crops mainly in the coastal area and the interior valleys; fruit trees, olive groves and vineyards in the hills; and pastures along with forest at the higher elevations.

Additional land use planning studies were financed by the EC in 1997 and in 2003. The latter produced a methodology based on the FAO's Framework for Land Evaluation (FAO, 1976) that was tested in different representative administrative areas (communes) of the country. The methodology was tested in detail also in the Preza Commune near the capital Tirana. Fig. II.9 shows examples of the results on land use planning derived from the Preza exercise based on recent soil survey data. Using national funding the study was expanded and applied in many other communes of the country. However, at national level no such study was ever completed. This should be a priority for the future.

## II.7 Natural resources conservation and management

A decade ago, it was estimated that in Albania, in only one year, erosion washes away 1.2 million tons of organic carbon, 100,000 tons of nitrate salts, 60,000 tons of phosphates, and 16,000 tons of potassium salts (Laze and Kovaçi, 1996). In the same period, Qilimi (1996) compared the status of soil fertility with the year 1976 and found out that it was decreasing, mainly in organic matter content, nitrogen, and potassium, resulting thus in soil nutrient mining. There is no evidence to prove that such situation has presently changed, unless worsened, especially due to continuing trend of fertilizer use reduction. A positive impact may be expected by the large expansion of alfalfa becoming recently the number one crop grown in the country. Zdruli (2005) reports accelerated soil erosion, deforestation, overgrazing, soil pollution, re-salinization, acidification, water logging, flooding, urbanisation and soil sealing, nutrient mining, and loss of soil fertility are perhaps the most alarming environmental problems in Albania.

**Fig. II.10. Evidence of land slides and collapse of abandoned terraces (left) and gully erosion on sloping lands (right).**

Other problems less described previously but equally important relate to riverbank and coastal erosion (Fig. II.11). In about 35 years (1970-2004) the Adriatic Sea relocated the coastal line in the area of Seman, Fier 150 metres inside land territory and the process is still continuing.

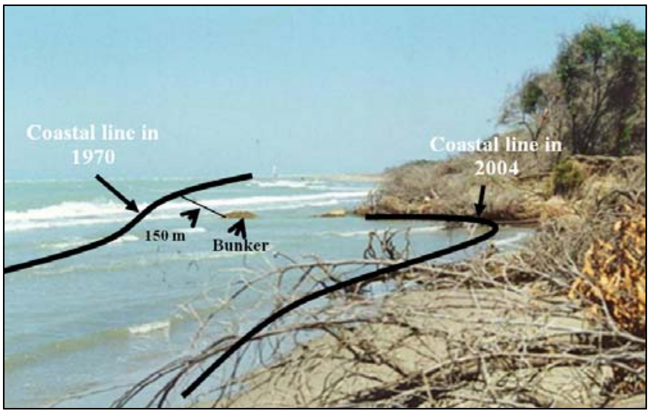



**Fig. II.11. Coastal erosion by the Adriatic Sea.**

Coastal erosion is becoming more prominent in the pace of accelerated erosion and increased solid sediments deposited by the rivers flowing into the Adriatic and Ionian Seas. Fig. II.12 shows a remote sensing image taken from the LANDSAT satellite in 2001, which measures depositions from the river Vjosa. It is estimated that every year around 50-60 ha are lost in the country due to soil erosion. Data are available also for **salinity build up** and expansion (in about 15,000 ha), **chemical pollution** from **heavy metals** especially in the areas around Ferro-Nickel mines (Librazhd and Pogradec), ferrochrome (Bulqizë), copper (Rubik, Kurbnesh, Fushë Arrëz), and in the surroundings of the Metallurgical complex (Elbasan), from resedimentation of Ni, Cr, Co, Cu and partly of Pb. All those values are above the accepted threshold values from EU countries.

Sallaku *et al.* (2002) reports that the soils around the Metallurgical complex of Elbasan in Central Albania are highly polluted with Cd, Zn, and Cu. The extent of pollution is much concentrated in a radius of 20 km from the industrial plant. In the oil-rich areas of Patos-Marinez, Kuçovë, Vlorë (about 45,000 ha), is revealed that concentration of Ni, Pb and Vn are above accepted thresholds. Point source pollution is a result of evidenced sources. They belong either to the areas of the former metallurgical and chemical industry, or sites of depositions and manipulation of subsoil sources. Malfunctioning of the drainage system has reduced also microbiological activity 3-4 times lower than in well-drained soils.

The Soil Science Institute based in Tirana has made a comprehensive study on heavy metal pollution in the country and has prepared a detailed map (Fig. II.13). The study indicates the presence of heavy metals in soils, derived from various sources, such as mines and processing plants. The majority of the polluted soils occur near industrial sites and, overall, they represent a small percentage of the total agricultural land of the country. By large, the majority of Albania's soils are healthy, but they need good management and stewardship.

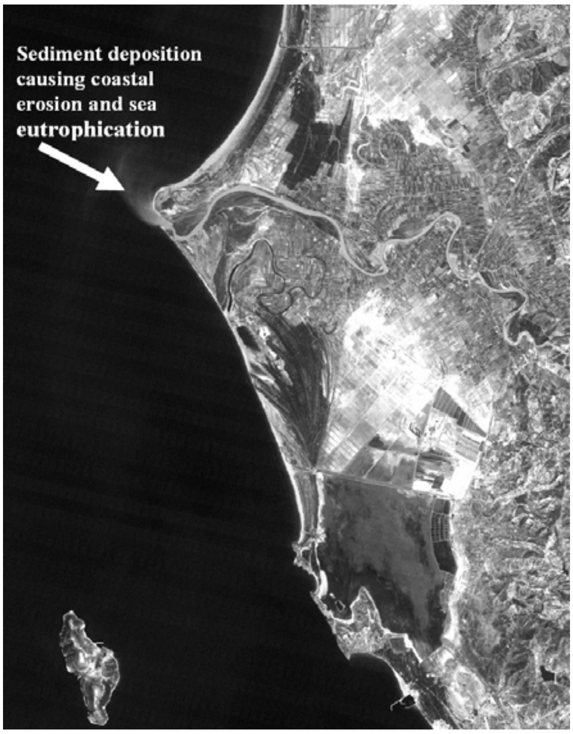



**Fig. II.12. Remote sensing image of Albania's coast.**

## II.8 Trends and Development Perspectives

The legal status and institutional strengthening for the conservation of natural resources is making progress. It is very plausible that Albania is one the few countries in the world to have a "Law for Agricultural Land Protection" (Law 9244, date 17.06.2004) signed by the President of the Republic of Albania on 17.07.2004. However the major constrain remains law implementation and enforcement. Deterioration of the forests and natural pastures are the most visible examples of such effects. The country is blessed with large areas of fertile soils, but the agricultural land in Albania is a finite resource and there are no left areas where the cropland could expand. Many mistakes were made in the past by converting natural pastures and forests to cropland and the negative results (massive landslides and accelerated erosion) of such actions are well known throughout the country.

To confront the challenges of sustainable development and environmental protection, the country needs to embark on immediate actions on land resources conservation and management. There may be many problems ahead and the road to economic prosperity might be bumpy. However, without its fertile soils, Albania will be much vulnerable to food crises that could derive also from potential regional conflicts. The country can't rely forever on imports for its food needs. Instead, it needs to develop its own domestic agricultural production, including agro processing, marketing and exports. A population increase and the anticipated tourism development would require for instance more local products rather than imported fruits and vegetables.

The following issues are proposed as priority areas of intervention for the short and medium period:

- Land degradation is a continuous threat to Albania's land resources and should be considered as a national priority.
- Conservation practices should be focused on: controlling erosion, improving soil fertility, improving the irrigation and drainage system, enhancing land consolidation, and promoting thus the sustainable use of land resources.
- Legislation for natural resources conservation and management should be completed and updated but most importantly implemented.
- Capacity building should be related to agricultural reform and institutional transformation. Coordination still remains an essential aspect that needs to be improved.
- All levels of governance and NGOs should promote increased public awareness on land degradation and soil conservation.
- Scientific research in agriculture, in addition to the plant nutrition issues and overall sustainable soil management, should also focus on environmental aspects.

- All these efforts should take in consideration the needs and interests of the farmers.
- During the last eight years, rehabilitation of drainage and irrigation systems has given results towards agricultural production growth, poverty lessening and farmer’s assistance.
- However, farmers need to get acquainted with the risk of excessive use of inputs in agriculture.
- There are seven major watersheds in the country. They can not be used as management units due to the several constraints, including erosions control in the highlands and flooding in the low-lying areas. This approach could avoid partial and non-efficient planning measures that follow administrative divisions.
- Land consolidation through farms enlargement or cropping systems should remain one of the priorities of Albanian government for agriculture development.
- To support many of the above action priority areas Albania needs to strengthen existing institutions like the Soil Science Institute and support detailed soil survey programmes. It is necessary to update present soil digital databases and establish monitoring procedures as early warning systems that control the status of land and water resources.

Collaboration at the Southeast European level could be strengthened further. This collaboration should include networking, information exchange and data sharing, as well as joint research projects, and mobility of scientists.

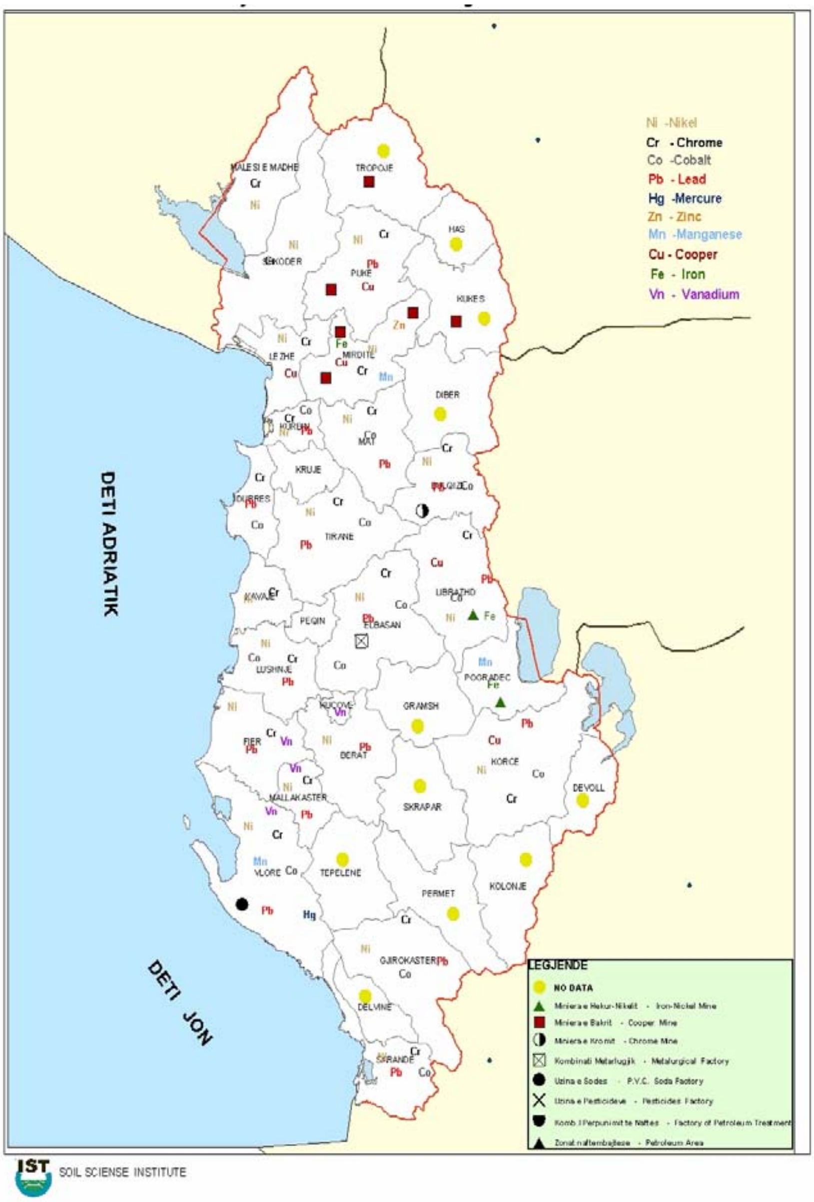



**Fig. II.13. Estimated heavy metal pollution in Albania.**

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# III. Land and hydrological potential of Bosnia and Herzegovina

Hamid Čustović[1] and Esad Bukalo[2]

1 Institute for Pedology, Agrochemistry and Melioration at the Agricultural faculty
University of Sarajevo – Head of the Institute and Professor of Soil Science,
St. Zmaja od Bosne 8, 71 000 Sarajevo, Bosnia and Herzegovina,
Tel.: +385 33 653 033; Fax: +387 33 667 429;
hcustovic@smartnet.ba or custovic.hamid@gmail.com

2 Federal Institute for Agropedology Sarajevo, Director of the Institute,
St. Dolina 6, 71 000 Sarajevo, Bosnia and Herzegovina,
Tel.: +387 33 268-262; Fax: +387 33 221 780;
uzbih@bih.net.ba

**Summary**

*The increase in food production can be in principle achieved in two ways: 1) by conquering new cultivable lands trough deforestation and 2) increasing per unit yield from the existing agricultural surfaces. The first method should not be employed if we have in mind the physical geography of the terrain and dangers of erosion, which might be triggered by the deforestation. Therefore, the second method remains, which consists in increasing the yield per unit area. It is possible to achieve that by applying modern technology, but on the other hand it is impossible to implement the modern technology on unreclaimed land. The reclamation of land is the key moment in the increase of food production, because unreclaimed land (exposed to floods and droughts, undrained, unlinked by roads, dispersed and scattered in small patches) were up to now also one of the important brakes to the faster development of agriculture. The yield of land farming, fruit-growing and vine-growing crop is at the low level in private sector of production. It is the consequence of the use of obsolete agricultural technology, which is becoming obvious in the application of mineral fertilizers. While in B&H their average consumption amounts to about 55 kg/ha of pure nutrients, in the Netherlands it amounts to 800 kg/ha. In spite of enormous wealth of water resources, the agricultural sector of B&H irrigates to date only about 10,000 ha, or 0,6% of arable lands or 1% of sowlands. On the state-owned farms, where modern technology is implemented, the yields are much higher, but this sector owns only a small percentage (4%) of the land, and furthermore, it is also undergoing the privatization processes during the transition. Bosnia and Herzegovina was not able to satisfy the needs in food through its own production even before the 1992-1995 war. Practically the key agricultural products and foodstuffs, like wheat, corn, vegetables, beef, vegetable oils and sugar were lacking.*

## III.1 Agriculture production zones

On the basis of pedo-climatic, geomorphological, hypsometric and production conditions, the agricultural production in B&H is divided into four production zones, as follows: (1) **flatland or lowland area** (up to 300 meters above sea level), (2) **hilly area** (300-700 meters above sea level), (3) **mountainous area** (above 700 meters above sea level) and (4) **Mediterranean zone** (bellow 700 meters of sea level). These zones, depending on type production and other characteristics are also named as: (a) grain-growing zone, (b) fruit-growing and livestock zone, (c) livestock-pasture-management zone and (d) zone of southern crop-growing or Mediterranean zone.

It is obvious from this survey that the B&H territory is mainly (83.5%) hilly mountainous region (Fig. III.1). Until now, little has been done to improve water and soil conditions in the hilly and mountainous territory while many things have been done which degrade and destroy the soil. By excessive forest cutting, ploughing of grass lands and uncontrolled cultivation of sloped terrains the status of land is further deteriorating not only in this area but even in the valley low-lands, low altitude regions with quality soil, numerous settlements, industrial facilities and communication routes the state is getting worse due to floods, erosions, torrents and deposits.

**Table III.1. Agriculture production zones of B&H.**

| *Zone* | *Area in ha* | *%* |
|---|---|---|
| 1. Flat-or low-lands zone | 577,758 | 11.30 |
| 2. Hilly lands | 1,344,693 | 26.30 |
| 3. Mountainous lands | 2,924,579 | 57.20 |
| 4. Mediterranean zone | 265,870 | 5.20 |
| **Total** | 5,112,900 | 100.00 |

The introduction of hilly water micro-reservoirs is of special importance because B&H has geomorphologic ally predisposition for construction of such facilities and they can serve a multi purpose function not only in irrigation but in water supply, fish-breeding, fire protection, flood control and development of tourism as well. The large financial resources invested into the protection of plain areas (river training, embankments, outfall drains, pumping stations) will remain ineffective for conservation of soil and water, both of agricultural engineering and technical nature, if not undertaken in the hilly-mountainous regions. Such measures would contribute to revitalizing the mountainous area and better protecting the flat lowland areas.

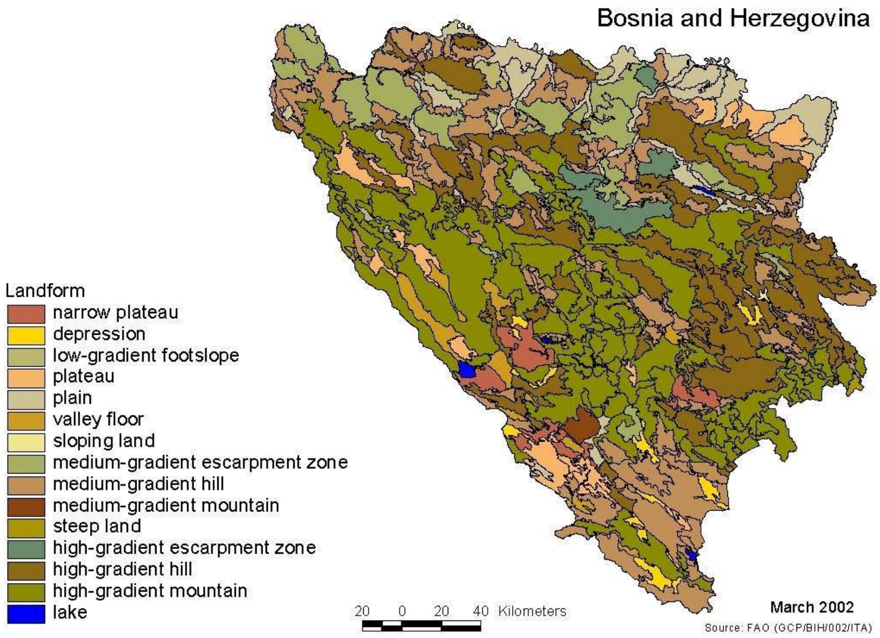


**Fig. III.1. Main geomorphological units of B&H.**

### *III.1.1 Flat or low-lands zone*

Flat or low-lands zone is found in the northern part of B&H and represents the most valuable land resource. The degree of development of primary and processing food production is much higher than in the hilly-mountainous areas. The following types of soil are present: flat or sloped hill-side pseudogley, marshy-gley soil, fluvisols, humofluvisols, eutric brown soils and fluvisols.

### *III.1.2 Hilly zone*

The hilly zone is more heterogeneous in terms of pedology. In this region, the *pseudogleys, vertisols, eutric brown soil, distric brown soil, brown soil on limestone, luvisols, marshy-gley, fluvisols and rendzines* are present. Considerable part of this zone is sloped above 13% and the processes of erosion are very marked. The erosion processes are further enhanced by excessive and inappropriate way of soil farming, lack of water and soil conservation measures and preference being given to row crops (corn and potato) on such terrains.

### *III.1.3 Mountain zone*

In mountain zones, mostly humus upon limestone, rendzines, rankers, brown soils on limestone, distric brown soils, fluvisols, podzols, marshygley, peat bog soils and colluvial soils are found. The erosion processes are present here too, although these lands are mostly covered by forests and grasslands. As for sowing crops, rye, barley, oats and potato dominate.

### *III.1.4 Mediteranean zone*

In the Mediterranean zone, mostly red soils (terra rossa), blacksoil upon limestone, brown soils upon limestone and marlstone, eutric brown soils, regosols, litosols and rocky soils are found. In view of the warmer climatic conditions this area has a possibility of growing a wide array of crops and of developing intensive farming, so that a part from land farming crops, the vegetable crops of early vegetables are also being cultivated for the market. Fruit-growing and vine-growing are also developed here, so that this region is also called the region of southern crops. Hypsometric distribution of altitude zones of Bosnian-Herzegovina territory indicates a very high altitude configuration.

**Table III.2. Altitude of B&H territory in %.**

| *Altitude above sea-level* | *Participation in %* |
|---|---|
| 0-200 | 14.2 |
| 200-500 | 29.0 |
| 500-1000 | 32.4 |
| 1000-1500 | 20.8 |
| 1500-2000 | 3.5 |
| >2000 | 0.1 |
| **Total** | 100.0 |

## III.2 Preferential land resources of B&H

Preferential land resources of B&H are found in the lowlands of Bosanska Posavina, larger river valleys and karst fields. As 87.2% of the territory of B&H is sloped above 8% and as the appropriate hilly-mountainous territory is less appropriate for introducing intensive agricultural farming, it is understandable that there exists a permanent interest that these lowlands should be used more intensively. In this region, all important settlements, industrial and many of the food processing capacities, road, railway and telephone communication routes can be found. A considerable part of these territories was exposed to floods, torrents and sediments coming hilly-mountain upland of their wider basin, which calls for an urgent protection measures. Approximately, the surface area of these territories is as follows:

**Table III.3. Distribution of preferential land resources.**

| *Territories* | *Area in ha* | *%* |
|---|---|---|
| 1. Bosanska Posavina | 200,000 | 50.0 |
| 2. Lager river valleys | 100,000 | 25.0 |
| 3. Karst fields | 100,000 | 25.0 |
| **Total** | 400,000 | 100.0 |

### *III.2.1 Bosanska Posavina*

In wider sense, it encompasses the areas along the right coast of Sava river, from Una river estuary to Drina river estuary. It comprises Bosansko-Dubička Ravan, Lijevče Polje, Srbačko-Nožićka Ravan, Ivanjsko Polje, Novigradska Posavina, Srednja Posavina with Objeda, Tinja-Brka, Gnjica-Lukavac, Semberija and Janja-Modran. This area was exposed to water erosion, because of the overflow of high waters of Sava river and its tributaries. Flood control, protection from mountain waters and torrents and basic drainage for major part of the region have been completed and conditions created for undertaking other measures of land reclamation, field drainage and irrigation. On the other hand, many facilities were damaged during the war and therefore need reconstruction.

### *III.2.2 Larger river valleys*

They include river valleys of Una-Sana, Vrbas, Ukrina-Vijaka, Bosna with tributaries, Lašva, Krivaja, Usora and Spreča basins, as well as the river valleys of Drina and Neretva. Except for the Neretva river valley, little was done in other river valleys to improve the water conditions and ameliorate the land although there is an obvious need not only to control the floods, but also to undertake measures of drainage, irrigation and land reclamation. In certain parts near cities river training was undertaken, but mainly with respect to urban and not rural needs. It should be emphasized that, particularly these terrains, were aggressively assaulted by construction of settlements and building of industry and traffic routes. In view of the fact that soils of highest quality are found here, there is a need to build a strategy of protection of terrains for the purpose of their being used in agriculture.

### *III.2.3 Karst fields*

These include four groups of karst fields, namely: (1) **karst field of south-west Bosnia** (Livanjsko, Duvanjsko, Glamočko and Kuprečko field); (2) **karst fields of east Hercegovina** (Popovo, Ljubinjsko, Trebinjsko, Bilećko, Ljubomirsko, Fatničko, Dabarsko, Gatačko and Nevesinjsko; (3) **karst fields of west Hercegovina** (Mostarsko blato, Ljubuško.Vitinsko, Imotsko-Bekijsko and Posuško polje); (4) **karst fields of central Bosna** (Glasinačko, Sokolačko and some smaller fields). In some of them incomplete works on flood control have been conducted (Popovo, Livanjsko, Imotsko-Bekijsko, Mostarsko field), but the major works on the regulation of soil water regime still remain to be done in practically all karst areas (drainage, irrigation). As these are the only land oases in the bleak landscape of naked karst, the need for an integrated amelioration of karst fields is both obvious and necessary.

## III.3 Hydrographic characteristics

Waters in B&H hydrographically belong to the Black Sea Basin (3.9 millions ha or 75.7% of total B&H surface area) and to the Adriatic Sea Basin (1.2 millions ha or 24.3%) although the precise lines of separation between these two basins have not yet been determined in all areas because of the hydrological complex nature of the karst. The Sava river is a recipient of water streams from northern part of B&H which belong to the Black Sea Basin, while the Neretva river is the only direct tributary of the Adriatic Basin.

### *III.3.1 Water impounding reservoirs*

Water impounding reservoirs in B&H were immediately after the Second World War built primarily for the purpose of utilizing the power potentials of water. In the course of time, they more and more assumed the nature of multi purpose impounding reservoirs. These reservoirs, as well as those built in later periods, are used for flood control, breaking of flood tidal waves, fish breeding (cage breeding), tourism and recreation, irrigation, and also for the electric power production. Until now (1992) there were built 26 impounding reservoirs with total volume of 3,8 billion m3 and average annual production of 5,248 GWh this accounting for 38% of the total annual production of electric power in B&H in 1991. In the next period, the construction of 38 more multi-purpose impounding reservoirs is foreseen.

### *III.3.2 Water pollution and protection*

Explosive development of industry and urban agglomerations in the period 1950-1990 caused an increase in pollution of watercourses, especially in Sarajevo-Zenica and Tuzla regions, where the development was most intensive. In 1970, the construction of 7 wastewater treatment plants began. The Laws on Quality and Protection of Water were passed, which compelled the polluters to introduce treatment plants and to modernize the technological processes.

During the 1992-1995 war, the quality of water in watercourses improved because the main industrial polluters either reduced their production and pollution or stopped working. However, after the end of the war, the rehabilitation of industrial plants is again going to lead to pollution, this meaning that it will be necessary to undertake further actions on water protection and preservation of quality. It is estimated that 20% of the-war pollution came from the Bosnia River Basin, 17% from the Neretva River Basin, 15% from Una River basin, 10% from Vrbas River Basin and 38% from other basins.

### *III.3.3 Water supply*

56% of the population was supplied with drinking water from the public waterworks (data from 1991). That was primarily urban population (94%) with daily consumption of 200-700 litres per capita. The structure of consumption of water from the public waterworks was as follows: (1) households 32%, (2) industry and other consumers 35%, (3) losses 33%. During the war, when even the water became a weapon of war (closing of valves, damages), the losses in the network increased (over 60%). Rural areas were mainly left to manage individually their water supply.

Today, with the help of the international community and through credit lines and donations aimed at improving the extremely difficult situation in the area of water supply, rehabilitation and additional construction of water systems is being undertaken in the majority of settlements. In the rural areas, which were the most destroyed during the war, efforts are being undertaken to build new water supply systems, which represent, necessary precondition for the return of population.

# III.4 Hydrological balance

### *III.4.1 Agro-hydrological balance in B&H*

**Precipitation** represents the greatest water resource of B&H. The yearly average of precipitation is about 1200 mm, which in terms of volume amount to 61.6 billion $m^3$. However, the precipitation is the most varying hydrological parameter in terms of space and time, the fact which is drastically obvious in the territory of B&H. The southern parts of B&H have average yearly precipitation about 2000 mm, central parts about 1000 mm and northern parts about 800 mm (Fig. III.2). These quantities are in rainy years considerably higher and in the drought years considerably lower. The seasonal variability is characterized by unfavorable distribution of precipitation over the year. This unfavorable distribution is from the point of view of agriculture particularly manifest in the southern parts of B&H, where the major part of precipitation comes in the colder season, when the consumption through evapo-transpiration increased. This is characteristic of Mediterranean precipitation regime. In central and northern parts of B&H the distribution of precipitation over the years is far more favorable of agriculture, bearing the characteristics of a continental regime.

**Potential evapo-transpiration (PET)** is far more balanced and stable parameter than precipitation. The average yearly PET of B&H is 725 mm is lower than the average yearly precipitation by 475 mm, which can be considered as very favorable circumstance for agriculture, because the major part of demands of plants for water can be provided by precipitation. In southern parts PET is considerably higher (900 mm) while it is lower in central (650 mm) and northern parts (700 mm). The basic characteristic of seasonal distribution of PET over the year is that it is in discrepancy with the precipitation, this discrepancy being considerably higher in southern than in central and northern areas (Fig. III.3).

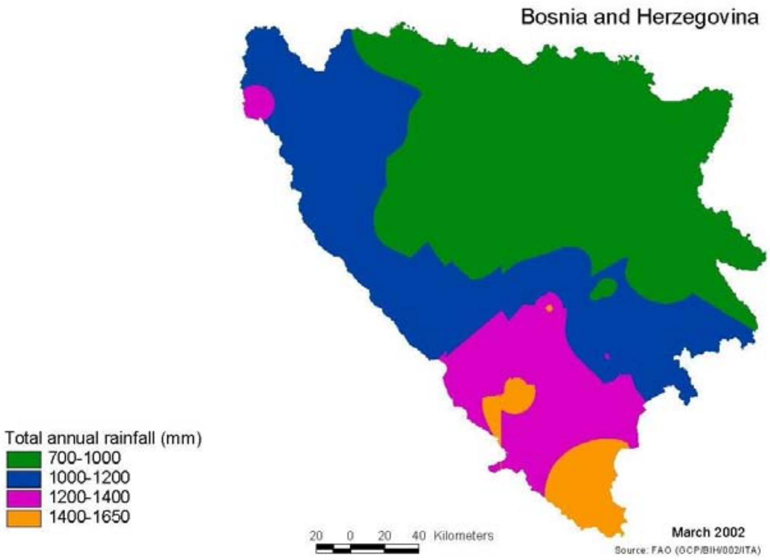


**Fig. III.2. Total annual rainfall zones.**

The **average yearly actual evapo-transpiration (RET)** throughout B&H is about 600 mm, but the differences between the average yearly RET and PET are the greatest in the southern parts (cca 300 mm), lower in northern (cca. 100 mm), and lowest in the central parts (cca 50 mm), while the differences throughout the territory B&H in average amount to 125 mm.

Following the result of agrohydrological budgeting based upon the entry parameters of precipitation, PET and soil water reserves (100 mm), we can come to relatively reliable data about the actual evapo-transpiration, shortages and surplus water. The average yearly shortage or demands for water irrigation in B&H amount to 125 mm. They are the greatest in southern areas where in average they amount to 300 mm, considerably lower in northern (100 mm), and lowest in the central parts. However, the demands in water, which might arise once in every ten years or in very dry years, are considerably higher. Because of that, the average yearly demands should be multiplied by the coefficient of 10 year needs, which is, depending on the area, 1.67 in southern parts, 4.0 in central, and 3.0 in northern parts, the B&H average being 2.75. Having this in mind, the 10-year demands in water would amount to 350 mm for B&H, 500 mm for southern parts, 300 mm for northern parts and 200 mm for central parts. These quantities should be ensured for cases of droughts, which can appear once every 10 years, which means that they should not be spent during the normal years.

If sometime in future all the flat-lands of B&H, amounting to 400,000 ha (Posavina, river valleys and karst fields) were to be irrigated then overall 10 year demands for water would amount to 1.4 billion $m^3$ or 4.5% of the total average yearly out-flowing potential of B&H. However, even in the super-optimistic 25-year prospects it could not be assumed that an area greater than 200,000 ha could be irrigated, this representing 0.7 billion $m^3$ or 2.2% of the total average yearly out-flowing potential of B&H. This shows that from the point of view of water supply there should be no problems as concerning the future irrigation projects in B&H, especially if the planned water impounding reservoirs be built. The average **yearly water surplus** in B&H amounts to about 600 mm. These surplus quantities are greatest in the southern parts, where they amount to ca 1400 mm, while in the central parts they are about 400 mm, and 200 mm in northern ones (Fig. III.3).

It is characteristic for the southern parts that they have the greatest yearly surplus which is in average 3.5 times greater than in central and 7 times greater than in northern parts. There is similar situation with shortages. They are in southern parts in average 6 times greater than in central and 3 times greater than in northern parts. This shows that in the southern parts of B&H the uneven distribution of water regime is most strongly expressed, and therefore the need for balancing the waters is greatest there. Application of irrigation is on one hand condition *sine qua non* of stable and intensive production, while on the other hand the water erosion is strongest in these regions. The water management is most complex in the southern parts, with disproportion being most strongly manifest, which does not mean that the same problems do not exist in central and northern parts of B&H, although they are less strongly expressed in these regions.

**Drought coefficient (RET/PET)** can be expressed in two ways: through the quantity of water deficit in mm and through the relationship between the real and potential evapo-transpiration (RET/PET), i.e. drought coefficient. The level of deficit or shortage of water was explained above, so we shall interpret only the drought coefficient (RET/PET) and its influence upon the reduced plant production yield. This coefficient for B&H is 0.83, for southern part 0.67, for central part 0.92 and 0.86 for northern part. On the basis of these coefficients, and taking into account Robelin's diagram, the droughts in B&H in average lower the yield for about 20%, in southern parts for about 38%, in central parts for about 10% and in northern parts for about 18%. This shows that the effects of droughts are most strongly expressed in southern parts, less in northern, and least in central parts, from which we can derive the conclusion that, regarding irrigation, the southern parts should be put on the top of the list of priorities.

**Potential out-flow coefficient (V/P) –** the relationship between the average yearly surplus water and precipitation in agrohydrological budgeting indicates the coefficient of potential out-flow. In B&H it is 0.5, which means that out of the total precipitation income the 50% go to out-flow. But here also there are great variations, depending on the area. In southern parts the average yearly coefficient of potential out-flow is 0.70, in central parts 0.40, and in northern parts 0.25. The characteristics of spatial distribution of main agro-hydrological parameters in B&H are illustrated in the Fig. III.3.

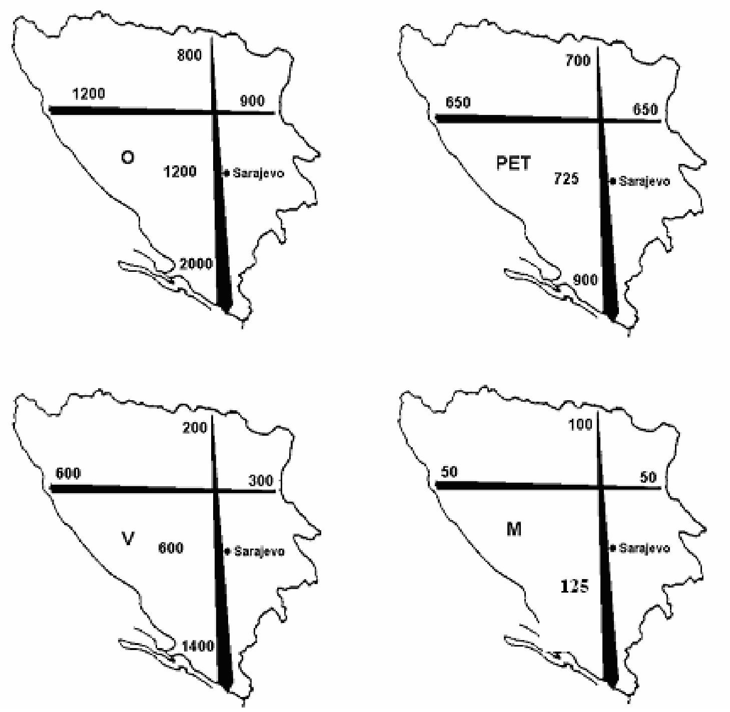


**Fig. III.3. Precipitation (O), potential evapo-transpiration (PET), surplus of water (V) and shortage of water are growing from the North to the South and from the East to the West of the country.**

If we take into account that the hydrologists deem those countries where the yearly mass of available water per capita is less than 1000 $m^3$ as water-stressed countries, then B&H would be ranked high because in average it has per capita out-flow potential amounting to 7500 $m^3$, and about 15,000 $m^3$ of precipitation potential. However, it is important to emphasize that B&H, from the point of view of water resources, has to eliminate the disproportion and to balance the waters to ensure better distribution of water in terms of time and space. It needs to control and manage the waters in more rational way.

The B&H agriculture meets 83% of its needs in water through the rainfall (rainfed system). This percentage could be increased through better choice of crops, which would use the natural distribution of precipitation in a more rational manner. In B&H, we rarely have a deficit of water in soil from October to May. By giving preference to “cool season crops”, which would use the winter precipitation moisture we could avoid the need to irrigate the land in certain areas.

The aim of any country is to ensure stable production of food for its population. This is because the experiences has shown that the complex nature of commercial, economic, transportation and interstate relationships usually presents serious obstacles to transfer food from one country to another. As B&H is presently providing only 50% of its needs in food, it is undoubtedly interested in increasing the agricultural production for the purpose of satisfying its overall needs, or even to ensure the export in certain branches of economy and certain products (cattle breeding, fruits).

In summary, B&H must develop a modern agricultural production, but in order to achieve that it must draw up a long-term plan for development of rural area. This plan will provide civilized conditions of living to its rural population. These conditions must be attractive not only for rural but for urban population as well. Until the moment that the peasant-farmer is not provided within his village or in the vicinity of his village all the benefits of modern civilization, the processes of de-agrarisation and devastation of villages and rural areas will continue. The rural areas will, in such case, be left without human resources. The newly created social changes that go along with the transition will only serve to speed up these processes.

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# IV. Overview of soil information and soil protection policies in Bulgaria

Milena Kercheva and Veneta Krasteva

Nikola Poushkarov Institue of Soil Science,
Shosse Banjya str. 7, Sofia 1080, Bulgaria;
Tel.: + 359 2 8246141; Fax: + 359 2 8248937
mkercheva@abv.bg; vnkrasteva@abv.bg

**Summary**

*The overview of soil information and soil protection policy in Bulgaria aims to elucidate some aspects of the long-term activities, responsibilities and achievements of the Institutions engaged with soil problems. The main sources of soil information such as soil survey, soil investigations, and soil monitoring are outlined. The availability and accessibility of soil data required for different purposes – assessment of soil degradation, land evaluation, accomplishing international projects on regional and national level, suggests implementation of soil geographic information system and updating the information for soil resources status. Three applications of primary soil data are demonstrated: use of pedotransfer functions for determination the reference values of bulk density in order to assess the aeration status of the main soil units; evaluation of agroecological resources on regional level, and preparing geo-referenced soil database for Bulgarian part of the Danube watershed for the project WDNH Action 4336 . The soil protection policy in the country is discussed in regard to the adopted legislation and non-governmental initiatives. The law for soil, which is under consideration, reflects the recent European policy and aims to protect soils from damages and destruction of their functions, permanent preservation of multifunctionality of soils, recovering their damaged functions by activities conformed with the environment and human health risks.*

## IV.1 Soil-resource-related institutions in Bulgaria

The first institution authorized to conduct soil investigations in Bulgaria was the agro-geological section of the Agricultural Experimental Station in Sofia founded on the initiative of the eminent soil scientist Nikola Poushkarov in 1911. Ten years later – in 1921 – a second research and educational center was created at the Faculty of Agronomy of the Sofia University St. Kliment Ohridsky. The Nikola Poushkarov Institute of Soil Science inherited these two research institutions and was established as the main soil research center of the country.

Nowadays there are several institutions with activities concerning soil resources and soil protection:

- **Ministry of Agriculture and Forestry** (MAF):
  - Nikola Poushkarov Institute of Soil Science (NPISS) – [http://www.iss-poushkarov.org]
  - Soil Resources Agency (SRA) – [http://www.soils-bg.org]
- **Ministry of Environment and Water** (MEW):
  - Executive Environment Agency – [http://nfp-bg.eionet.eu.int/ncesd/]
  - Regional Environment Agencies.
- **Bulgarian Academy of Sciences**:
  - Forest Research Institute – [http://www.fribas.org]
- **Educational centers**:
  - Agrarian university /Faculty of General Agronomy/ in Plovdiv – [http://www.au-plovdiv.bg]
  - University of forestry /Faculty of Agronomy/ in Sofia – [http://www.ltu.bg]
  - University of architecture, civil engineering and geodesy /Faculty of Geodesy, Department Land Management and Agrarian Development/ – [http://uacg.bg]
  - Sofia University St. Kliment Ohridsky /Faculty of Geology and Geography/ – [http://www.uni-sofia.bg]
- **Non-governmental organizations** (NGOs):
  - Bulgarian Soil Science Society
  - Bulgarian Humic Substances Society.
  - Bulgarian Soil Tillage Research Society

Each of the above mentioned institutions has a specific contribution and place in the realization of the main purposes of the soil science – preservation and improvement of soil productivity, protection of soil resources and environment. The aim of this paper is to elucidate the current status of two aspects of these long-term activities – the collected soil information and soil protection policies in our country.

## IV.2 Sources of soil information

### *IV.2.1 Soil survey and soil mapping*

Soil survey and mapping are main source of information for the soil resources of the country. A detailed historical overview of the outcomes of these activities was published by Kolchakov et al. (2005) in the Research report No. 9 of the European Soil Bureau. Here we will focus on the up-to-date use of the most frequently utilized sources of soil information such as:

- **Large scale soil survey**. Soil maps and reports prepared on the basis of **soil surveys at 1:25000 scale** conducted for the period 1956-1988 and at 1:10,000 scale, started in 1971. They contain information for distribution of the recognized soil units, climate characteristics and data for:
    - Soil profile morphological description.
    - Soil particle size distribution and texture classes (pipette method, Katchinski, 1956).
    - pH in KCl (1:2.5 soil 1N KCl extract, pH meter).
    - Humus content (method of Tjurin).
    - Total amount of nitrogen (method of Kieldal).
    - Total amount of phosphorus (method of Ginsburg).
    - Calcium carbonates (method of Shaibler).

  The advantage of this information is that it is a detailed information, covers the whole territory of the country and has been done by unified methodology. The reports contain data for more than 50 000 main soil profiles (Kolchakov et al., 2005). The obstacles for direct usage of these information which have appeared especially during the international projects concern the soil classification system, the methods used for some of the soil properties (e.g. soil particles size distribution), the lack of geo-reference information for the soil profiles. Some of these problems have been overcome by elaborating harmonization between different systems and methods. The identified soil units according to the national soil classification were correlated to the Soil Taxonomy (Boyadzhiev, 1994a), to the FAO-UNESCO-ISRIC revised legend (Boyadzhiev, 1994b), to the World Reference Base (Teoharov, 2004). The soil particle size distribution determined by the method of Katchinski (1956) is transformed to soil texture classes according to the Soil Survey Staff (1993) by graphical interpolation or by the transformation method proposed by Rousseva (1997). The Soil Resource Agency (SRA) is responsible for maintaining the country's digital soil map and has digitized soil maps at 1:10,000 scale of about 80% of arable lands in AutoCAD Map 3[3]. The agency conducts soil survey and actualizes the soil information upon request for the purposes of agricultural land evaluation, re-categorization of lands, investment projects, etc. The organization of computer database and recording of the analytical data of 130 soil survey reports has been commissioned for the purposes of the project Action 4336 – Floods and other weather-driven natural hazards. Prediction and Mitigation (Kolev, 2006).

- **Soil map of the whole territory of Bulgaria at 1:400,000 scale** (Koinov et al., 1968). It is based on 1:25,000 scale soil survey and is considered as one of the most representative and suitable for a lot of operational purposes. The last digitized version of this map is prepared by Soil Resource Agency in 2002.

The main challenges concerning the primary soil information are the accomplishment of the soil geographic information system, updating the information for soil resources of the country as well as elaborating a digitized map at 1:100,000 and/or 1:250,000 scales.

## IV.3 Soil studies

### *IV.3.1 Analytical data*

Analytical data and description of the main soil units could be found in the monograph "Soils of Bulgaria" (Antipov-Karataev et al., 1960), Atlas of Bulgarian Soils (Koinov et al., 1998), monographs and habilitation theses on main soil characteristics

[3] Available via [http://nfp-bg.eionet.eu.int/cds_eng/mzg11.htm].

(Voinova-Raikova, 1960; Raykov, 1971; Dinchev, 1983; Dilkova, 1985; Ganev, 1992; Stoichev, 1997; Filcheva, 2004; Stoicheva, 2006, etc.), project research reports (Archive of the N.Poushkarov Institute of Soil Science), data collection issues (Ganev, 1990). Other sources of information are long-term field experiments carried out in different agroecological regions concerning:

- **Management water and nutrient cycles for improvement of soil fertility –** e.g. the “Yield prediction” complex program (1972-1990 year) for obtaining information concerning parameters of carbon, water, and nutrient balances for the main agroecological regions in the country (Stoichev, 1997; Stoicheva, 2006);
- **Studies on soil degradation and on conservation** agricultural practices for soil degradation prevention **–** e.g. field plots for erosion studies (Rousseva et al., 2006), experiments on saline soils (Popandova, 2004);

### *IV.3.2 Data assessments*

Information for soil hydraulic and physical properties is often insufficient or lacked for implementation of GIS for assessment and mapping of soil physical degradation, soil erosion, application of hydroulogical models, etc. This could be overcomed to some extent by using pedotrasfer fuctions between routine soil survey data and the desired soil property. Such approach is used by Rousseva (2001;2002; 2005a) for determining soil profile permeability class.

Another parameter, which is involved in the primary data set for monitoring, is the soil bulk density. This indirect indicator of the soil aeration status is a dynamic parameter depending on natural and anthropogenic factors. Using experimental data for 22 representative soil profiles from virgin lands the reference values of bulk density have been calculated for each textural class of A and B horizons (Kercheva, Dilkova, 2005). The optimal, critical and limiting values of bulk density are calculated at 20% (15% for fine textured soils – physical clay (<0.01 mm) >45%), 10% and 5% drainage-aeration pores, respectively, using experimental data for particle density (ds) and field capacity (FC) (Kuznetsova, 1990):

$$B_{opt,crit,lim} = \frac{(100 - AP_{opt,crit,lim}) \cdot d_s}{100 + FC_{w} \cdot d_s} \qquad (1)$$

It is found that most medium textured soil layers from A horizons have optimal bulk densities – 1.0-1.2 g/cm$^3$, while in fine textured soil layers, bulk densities classified as critical and limiting vary from 1.2 to 1.35 g/cm$^3$ in average. In fine textured illuvial horizons the aeration conditions are unfavorable (1.25-1.60 g/cm$^3$) because of limiting content of drainage aeration pores. Medium textured illuvial soil layers have better aeration status and there are cases with optimal (1.0-1.2 g/cm$^3$), but also with critical and limiting values of bulk density (1.55-1.75 g/cm$^3$). For each textural class of A and B horizons regression equations between the measured field capacity and humus and clay content (<0.001mm) (Table IV.1) and between the calculated reference bulk density values and humus and clay content (<0.001mm) were found (Table IV.2, Fig. IV.1 and Fig. IV.2), which could be useful when field capacity and soil particle density data missed (Kercheva, Dilkova, 2005).

**Table IV.1. Regression equations of field capacity (FC) with humus (hum) and clay (<0.001mm) content ($cl_1$) for different textural classes (Kercheva, Dilkova, 2005).**

| Physical clay < 0.01 μm, % | FC, %w/w | $R^2$ | SEE |
|---|---|---|---|
| Humic horizons: A, $A_1A_2$, $A_2$ | | | |
| 10-30 | 6.7+8.9hum | 91.1 | 2.9 |
| 30-45 | 14.5+5.5hum | 70.5 | 4.7 |
| 45-75 | 11.6+3.5.hum+0.32$cl_1$ | 72.0 | 3.9 |
| Illuvial horizons: B | | | |
| 30-45 | 19.4+5.9hum | 71.8 | 1.2 |
| 45-60 | 10.0+0.44$cl_1$ | 43.0 | 3.2 |
| 60-75 | -10.5+0.86$cl_1$ | 40.3 | 4.9 |

**Table IV.2. Regression equations of optimal, critical and limiting bulk density with humus (hum) and clay (<0.001mm) content ($cl_1$) for different textural classes of A horizon (Kercheva, Dilkova, 2005).**

| Physical clay< 0.01 mm, % | $BD_{opt}$ g/cm$^3$ | $BD_{crit}$ g/cm$^3$ | $BD_{lim}$ g/cm$^3$ | $R^2$ | SEE |
|---|---|---|---|---|---|
| 10-30 | 1.75-0.22.hum | 1.97-0.27.hum | 2.07-0.27.hum | 86 | 0.10 |
| 30-45 | 1.49-0.10.hum | 1.67-0.12.hum | 1.77-0.12.hum | 76 | 0.06 |
| 45-75 | 1.58-0.06.hum-0.005 $cl_1$ | 1.68-0.07.hum-0.005 $cl_1$ | 1.77-0.08.hum-0.005 $cl_1$ | 73 | 0.07 |

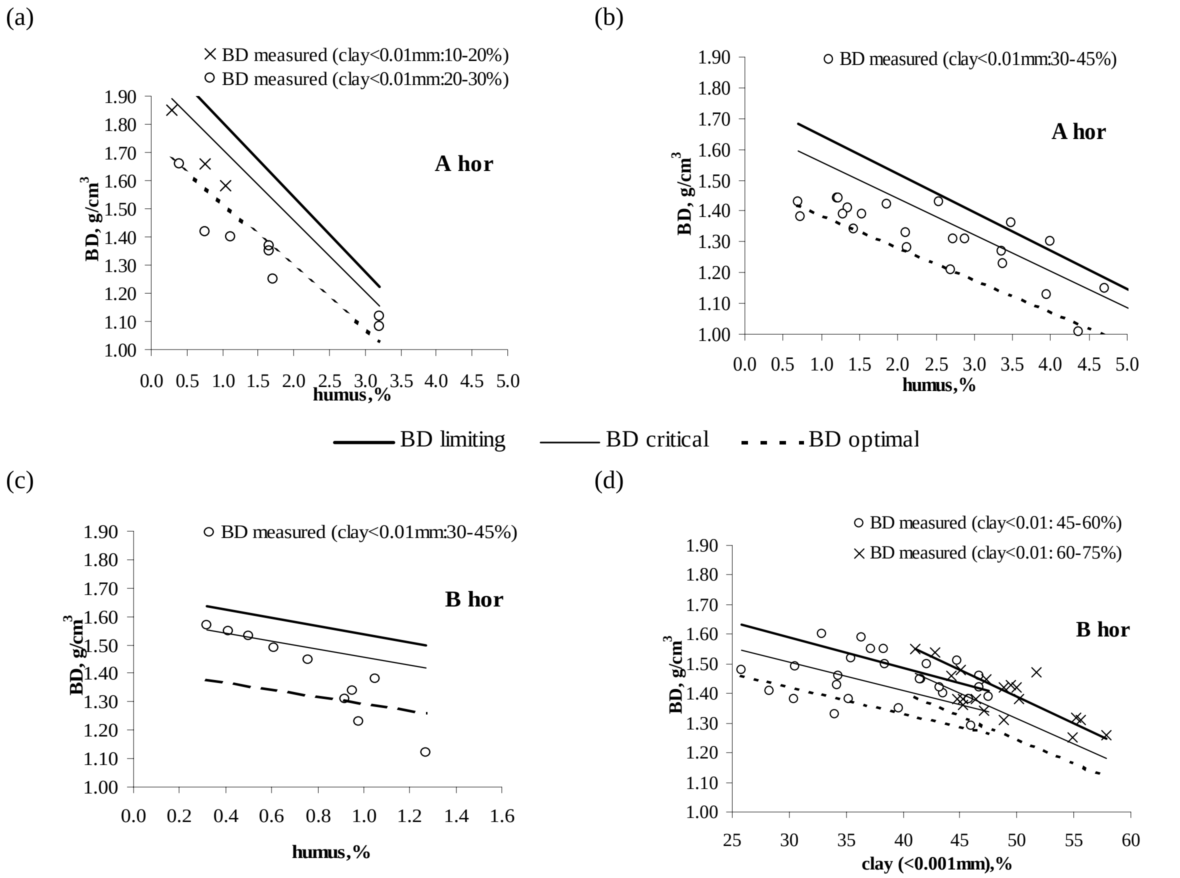


**Fig. IV.1. Measured values (BD measured) and relationships of the optimal, critical and limiting values of soil bulk density (BD) of A and B horizons for different textural classes. (Kercheva, Dilkova 2005).**

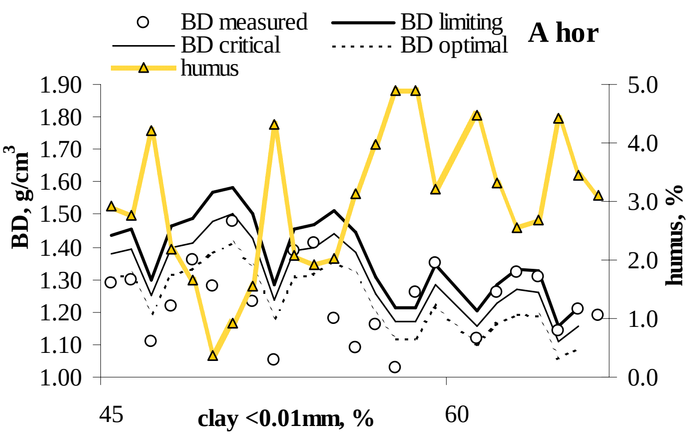


**Fig. IV.2. Measured values (BD measuered) and calculated optimal, critical and limiting values of soil bulk density (BD) of A horizons (clay<10 µm = 45-60 and 60-75%) (Kercheva, Dilkova, 2005).**

### *IV.3.3 Soil monitoring*

The Executive Environment Agency is responsible for observation and control network on environmental components of our country in particular on soils. This Agency provides data and issues periodical Bulletins and Annual Bulletins for the State of Environment. The National Catalogue of Environmental Data Sources [http://nfp-bg.eionet.eu.int/cds_eng/] contains data about where and what environmental information is available in Bulgaria, in particular for land and soil.

Poushkarov Institute of soil science collaborated with EEA in the frame of the projects "Overview, assessment and recommendation for re-organization of soil monitoring grid" (Dinev, 2003) and "Development and implementation of a soil monitoring and assessment for the Republic of Bulgaria" (Kolev, 2004). Since 2005, a soil monitoring network of 446 points situated in a grid 16×16 km has been set as a part of the **EuroSoilNet** program. Soil samples from 0-20 and 20-40 cm soil depth are analyzed for pH, organic carbon, and bulk density. The main objectives of the national soil monitoring system are:

- Control and soil protection from heavy metal (Zn, Cu, Pb, Cd, As) pollution;
- Control and soil protection from organic pollutants (PAH, PCB and pesticides);
- Control and soil protection from acidification;
- Control and soil protection from salinization;
- Control and soil protection from erosion;

## IV.4 Application of soil information

The recent main groups of applications of collected soil information are schematically presented in Fig. IV.3.

### *IV.4.1 Land evaluation*

Land evaluation is applied in the cadastre of the agricultural lands as a measure of natural fertility of each cadastre parcel, private property or larger agricultural region (Petrov et al., 1988). In the latter case the land evaluation is based on the ago-ecological characteristics which account for both soil and climatic conditions. The agro-ecological regions (Yolevski et. Al., 1980) are determined on the basis of the dominant soil type, water and heat resources, especially during the vegetation period, climatic extremes, altitude, relief, etc.

Land evaluation is used for planning the activities for better territorial and agricultural management, rational crop selection, investments in plantations of perennial plants, assessment of the theoretical crop yield, etc. Land evaluation is a basis for economic assessment of soil resources, as well as it could be used as criteria for calculation of land taxes.

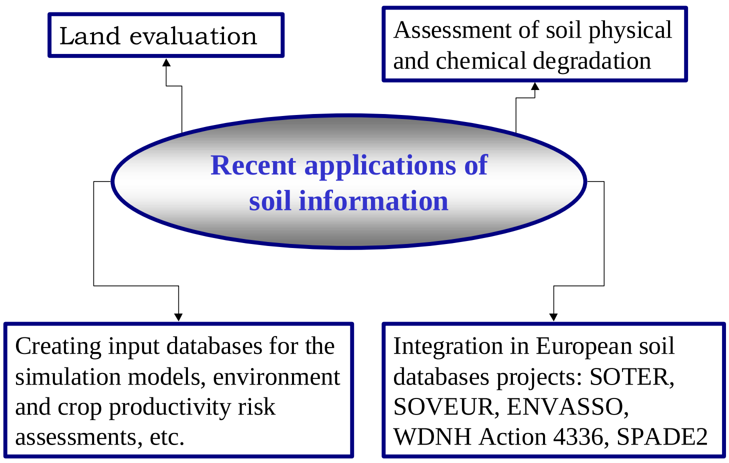


**Fig. IV.3. Recent applications of soil information.**

The methodology of land evaluation is elaborated in the Institute of N. Poushkarov Soil Science and recently it has been updated with adopting the FAO recommended land evaluation principles (Sys et al., 1991). The evaluation of soil fertility is based on the most significant factors for the agricultural plant development and productivity.

The rank (from 0 to 100) regarding the particular crop requirements is assigned to each of the following soil parameters: soil texture of the arable layer ($R_{TX}$); thickness of the humic horizon ($R_{THH}$); thickness of the entire soil profile ($R_{TSP}$); the ratio between the contents of clay (<0.001 mm) of B horizon and A horizon ($R_{CCR}$); soil acidity of the arable layer ($R_{pH}$); humus content in the arable layer ($R_{HC}$); groundwater table ($R_{GWT}$). The field rank ($FR_x$) for a particular crop (x) is the average value of the ranks of these $n^R$ soil parameters:

$$FR_X = \frac{R_{TX} + R_{THH} + R_{TSP} + R_{CCR} + R_{pH} + R_{HC} + R_{GWT}}{n^R} \cdot k_{EA} \cdot k_{SA} \cdot k_{ST} \cdot k_{FL} \cdot k_{CL} \qquad (2)$$

where the adjustment coefficients **k** (0-1) account correspondingly for:

- $k_{EA}$ – soil erosion/accumulation;
- $k_{SA}$ – salinity/alkalinity;
- $k_{ST}$ – stoniness of arable layer;
- $k_{FL}$ – flooding;
- $k_{CL}$ – climate condition in respect to water and heat requirements of the crop.
- $K_I$– presence of irrigation system.

The land suitability is classified according to the FAO recommendations (Sys et al., 1991) as: S1 – lands without any restriction (FR>75) and with insignificant restriction (FR=65-75); S2 – lands with moderate restrictions (FR=50-65); S3 – lands with substantial restrictions (FR=40-50); N – lands with extremely serious restrictions.

Last years the traditional land evaluation methods are coupled with GIS in order to assess the agro-ecological resources on district level (Georgiev and Krasteva, 2005). A case study of Vratsa district situated in west part of Danube plain illustrates this approach. Data obtained from long-term climatic and soil investigations show that the territory of the district could be divided into 5 agro-ecological complexes. The suitability of 16 crops for growing in each of the agro-ecological regions of Vratsa district are presented and classified in Table IV.3.

**Table IV.3. Suitability of the agro-ecological regions No 1, 2, 3, 4, 5a (less than1000 m a.s.l.) and 5b (more than 1000 m a.s.l.) in the district of Vratsa for different crop growth.**

| Crop | 1 | 2 | 3 | 4 | 5a | 5b |
|---|---|---|---|---|---|---|
| Wheat | 77 | 92 | 68 | 69 | 52 | 0 |
| Maize | 65 | 88 | 53 | 49 | 35 | 0 |
| Sunflower | 61 | 85 | 58 | 58 | 31 | 0 |
| Sugar beet | 66 | 78 | 51 | 57 | 38 | 0 |
| Oriental tobacco | 46 | 37 | 42 | 27 | 41 | 0 |
| Tobacco | 58 | 84 | 59 | 60 | 15 | 0 |
| Potato | 17 | 24 | 28 | 47 | 66 | 66 |
| Vineyard | 94 | 87 | 72 | 44 | 37 | 0 |
| Apple | 67 | 81 | 51 | 47 | 40 | 0 |
| Pear | 66 | 78 | 52 | 49 | 40 | 0 |
| Plump | 55 | 83 | 60 | 68 | 53 | 0 |
| Peach | 51 | 69 | 52 | 33 | 57 | 0 |
| Cherry | 79 | 71 | 60 | 38 | 46 | 0 |
| Lucerne | 49 | 95 | 57 | 48 | 23 | 0 |
| Pasture | 57 | 73 | 72 | 72 | 58 | 58 |
| Tomato | 87 | 85 | 61 | 50 | 31 | 0 |
| **Mean suitability** | **69** | **83** | **61** | **59** | **47** | **10** |

| Legend | S1 | S2 | S3 | N |
|---|---|---|---|---|

## IV.5 Information for soil physical and chemical degradation status

The recent reports (Stoichev at al., 2000; Dilkova et al., 1998; Rousseva, 2006; Rousseva et al., 2006) on degradation of Bulgarian soils stressed on factors (decline of organic matter, soil structure deterioration, unbalanced fertilization, etc.), soil susceptibility, extent and tendencies of different type of soil degradation. Most of the estimations are based on collected soil data during long-term research investigations (e.g. Dilkova, 1985; Rousseva, 2000; Filcheva, 2004; Popandova, 2004).

The up-to-day information concerning land degradation in Bulgaria in agriculture, forestry and other sectors, could be found on the web-site of the project "Capacity building for sustainable land management in Bulgaria" (Rousseva, 2006): [http://unccd-slm.org], as well as in the annual reports of the Executive Environment Agency (last issue: EEA, 2004). The analyses (Rousseva, 2006) of the identified sources show that the water and wind erosion of soils impact the largest areas – 3,730,000 ha (76% of agricultural lands) and 1,350,000 ha (24% of the areas of agricultural lands), respectively. About 1,500,000 ha in cultivated lands are acidified and 35,500 ha salinizied.

Last years' thematic maps on soil degradation processes:

- **Map of soil vulnerability to acidification** (Stoichev and Kolchakov, 1998). On the basis of soil survey records for the main soil units it was estimated that about 4.3 milions ha of land is vulnerable (non-resistent) to acidification (pH<5).
- **Map of soil susceptibility to water erosion** for the territory of Bulgaria, scale 1:100,000 (Rousseva, Stefanova, 2005a). It was found that soil erodibility (USLE-K) for 77.3% of the soil mapping units and 61.5% of the country's territory was higher than 0.03 t ha h/ha MJ mm;
- **Map of soil susceptibility to deflation** for the territory of Bulgaria, scale 1:100,000 (Rousseva, Stefanova, 2005b). Soils susceptibility to wind erosion (WEQ-I) varies between 100 and 375 t $ha^{-1}$ $y^{-1}$ and soils with susceptibility higher than 150 t $ha^{-1}$ $y^{-1}$ cover 85% of the territory of Bulgaria;
- **Map of cites and extent of saline soils** (Popandova et al., in press);

## IV.6 Integration in European soil databases projects

The rich archive of the Poushkarov Institute of soil science has been used to select representative soil profiles data as parts of several International projects. One of the advantages of these projects is that they enforce the harmonization and modernization processes of the organization of soil database.

The Bulgarian contribution in the projects "Floods and other weather-driven natural hazards – Prediction and Mitigation (WDNH) – Action 4336" was to provide a database of soil and related information from 1250 geographic points of the Danube Basin of Bulgaria (Kolev, 2006). For this purpose soil profiles from the maps of the soil survey reports at 1:10,000 scale have been geo-referenced on the same scale topographic maps. The criteria for the soil profiles selection were the area of the soil unit (Fig. IV.4) in the region, vulnerability to flooding (e.g. Fluvisol), completeness of the data, proximity to soil monitoring point of the 16×16 km grid of the Ministry of Environment and Waters.

## IV.7 Soil protection policy

In this last section of the report an overview of the governmental and non-governmental initiatives concerning soil protection is presented. There are several acts concerning soil:

- Law for agricultural lands protection (State Gazette №35/24.04.1996, last amendments №14/ 18.02.2000 and №26/ 29.03.2000). Regulates protection from damages, restoration and improvement of agricultural lands and determines the conditions and regulations for alteration of their purpose;
- Environmental protection act (State Gazette №91/25.09.2002, last amendments, 2005). Last amendment designates soil as a component of environment subjected to special legislation and stipulates elaborating a Law for soil;
- Law for property and use of agricultural lands (State Gazette №17/01.03.1991) Regulates property and use of agricultural lands;
- Regulation №3 (S.G, №36/8.05.1979, amendments №5/1996, №54/1997, №21/2000). Determines the norms for permissible content of harmful substances in soil;
- Regulation №26 (S.G. №89/22.10.1996) for recultivation of destroyed lands, improvement of low productive lands, removing and using of humic layer)
- Law for soil (under consideration). Regulates the responsibility of the governmental institutions on national and regional level:
    - Ministry of environment and water elaborates national program for soil protection, sustainable soil use and soil restoration;

- Ministry of health is responsible for health risk assessment;
- Ministry of regional development and public works organizes monitoring and geo-protection from erosion and landslides
- Responsible institutions on regional level – mayor

The law reflects the recent European policy and aims to protect soils from damages and destruction of their functions; permanent preservation of multifunctionality of soils; recovering their damaged functions by activities conformed with the environment and human health risks.

Non-governmental organizations have special place for broadcasting knowledge on soil problems. Their activities are concentrated in organization conferences on different topics. Recent conferences devoted to soil protection are:

- National conference with international participation "90 Years Soil Science in Bulgaria" – 2001, Sofia;
- First national conference on humus substances and soil tillage, 2000, Borovetz;
- Second national conference with international participation on humus substances, 2004, Borovetz;
- National conference with international participation "Management, use and protection of soil resources" 2005, Sofia;
- International conference "Soil Science – Base for Sustainable Agriculture and Environment Protection" 13-17 May 2007, Sofia.


**Fig. IV.4. Bulgarian part of the Danube watershed. Soil map units according to FAO legend (based on map M1:400 000, Koinov et al., 1968).**

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# V. Croatian Soil Information System within the Environment Information System

Hana Mesić, Zoran Major, Marijo Vranaričić, Andreja Čidić

Croatian Environment Agency,
Zagreb, Trg maršala Tita 8, Croatia
Tel.: + 385 1 4886 840; Fax: + 385 1 4886 850
hana.mesic@azo.hr; zoran.major@azo.hr; marijo.vranaricic@azo.hr; andreja.cidic@azo.hr

**Summary**

*Environment Information System (EIS) consists of numerous dislocated but correlated databases, thematically organized by basic thematic areas – environment components like: soil, water, air, biodiversity, marine environment, etc. Croatian Environment Agency (CEA) is responsible for EIS development and conducting. Databases are partly located at CEA, but more of them are dislocated within institutions in charged by specific legislation acts. CEA has a task to connect relevant data and databases in unique EIS and, in that term, to act as a central information hub. Croatian Soil Information System (CROSIS) as a part of EIS is considered as key instrument for relevant soil state data collection and processing of data with aim to shape and govern environment policy; Soil Protection Strategy, Soil Protection Law and other relevant political instrument. In that term CROSIS role is crucial for planning and conduction of other relevant activities (sustainable agriculture and forestry development), especially in protected areas such as national parks, protected water area, etc.). CROSIS development rely on EIS development in one hand, but its functionality, after establishment, is also depended on Soil Protection Act which is still not in force.*

## V.1 Introduction

The goal of this report is to present activities so far conducted and achievement in Environment Information System (EIS) developing process, especially considering Croatian Soil Information System (CROSIS) development. Given overview is focused on so far developed databases, planned databases, connections and relations between EIS parts and its contents. Data flow system is already established in thematic areas such as waste management/material flow. Other thematic areas databases and data flow systems are under development – differences that occurred are mainly results of lack of various legal background documents regarding prescribed data collecting procedures. Waste and air protection thematic areas, for example, have a number of laws and regulations which prescribe data flow rules. Other thematic areas, such as soil protection and similar, do not have such political background for data collecting procedures. This leads to more or less voluntary approach on data collection. Croatian Environment Agency (CEA) is dealing with this issue by development of a Soil Monitoring Program, as a base for needed regulation. At the same time, CROSIS project started in 2006. Both activities have to be accompanied by Soil Protection Law, which is being developed under jurisdiction of Ministry of Environmental Protection.

### *V.1.1 Croatian Environment Agency – CEA*

CEA is a public institution founded in June 2002 by the Government of the Republic of Croatia as the central institution for collecting and combining of the environmental data on the State level, for the purpose of processing that data, running an environmental database, monitoring and reporting on the condition of the environment. CEA is the national focal point of cooperation with the European Environmental Agency (EEA) and is a part of the European Environment Information and Observation Network (EIONET). According to its responsibilities, activities of CEA comprise of environmental data collecting, merging and processing, maintain EIS databases and report about state of environment. Main activities and responsibilities are:

- Ensuring for the state bodies, the Government and the Parliament, all the necessary information for efficient implementation of the policy on the environmental protection,
- Developing and coordinating the integrated information system of environmental protection which is to be connected to the system for monitoring of the environmental conditions,
- Founding and maintaining the reference centers with databases that are important to follow the state of the environment (socio-economical data, environmental pressure, environmental stats and quality),

- Developing models for processing data on the environment, as well as their evaluation (modeling, predictions and visualization),
- Providing expertise and performing consultation tasks – while determining the content, methodology and manner of monitoring of the environmental conditions, as well as determining, supervising and following-up the projects and programs on environmental protection,
- Improving comparativeness and quality of environmental data,
- Providing reports on the general state of the environment in the Republic of Croatia, tendencies, and the implementation policy of the successful instruments in the priority themes of environmental protection, as well as on the sector priorities (thematic reports),
- Providing reports on special issues in the environmental protection, like the areas with higher radioactivity, environmental and health quality, etc.
- Assisting the administrative bodies to develop new policy in environmental protection, as well as to follow the developments in the action programs of the environmental protection,
- Cooperating with the European Agency for the Environmental Protection (EEA) and acting as the part of the European Environment Information and Observation Network (EIONET),
- Cooperating with legal and physical entities, international bodies, institutions and other associations on elaboration and realization of projects and programs of environmental protection,
- Ensuring access to environmental information by the use of modern technology and communication standards in compliance with European requirements,
- Ensuring access to environmental information on the Republic of Croatia, and permitting its usage and exchange.

### *V.1.2 Environment Information System – EIS*

The Environment Information System (EIS) encompasses a wide array of data and information on air, soil, water, marine, biological and landscape diversity, climate, cultural heritage, spatial properties, waste, as well as other data of environmental relevance. EIS is considered as a crucial Governmental instrument for creating and monitoring of sustainable policy development and implementation. *The 1994 Law on Environmental Protection* sets the obligation to develop and maintain of EIS. Subsequently, the *By-Law on Environmental Information System* was adopted in 1999, prescribing the EIS contents and methodology, obligations of the participating institutions, the manner of submitting and methods of processing of environmental data and the requirements for the implementation of EIS Management Programme.

Despite all the efforts so far, a fully functioning EIS has not been completed yet. At the moment, Croatia is dealing with the lack of primary data on the state of environment, the lack of meta-data on the already existing data, the lack of relevant statistical data, and especially the lack of qualitative and quantitative data on interconnections between the development activities and the state of the environment.

CEA is developing databases and data flow network for targeted priority thematic areas, and information systems/subsystems ensuring their integration to unique Environment information system. EIS development is in line with methodology defined by EEA and specific national needs prescribed by the regulations. At the moment, hardware and software core of EIS has already been established on the CEA servers. The available system consists of currently developed databases such as **Corine Land Cover** (CLC), **Environment Projects Database**, **Landfill Cadastre**, **Geo-referenced database of Polluted and suspect-polluted locations**, etc. One of the main requirements that have to be fulfilled is EIS “openness”. That means that the system is open for data exchange between different internal and external systems via specific interfaces, depending on the topic area.

The EIS functionality is primarily set up as a co-operative information system made of numerous dislocated, independently built, co-ordinated and inter-linked information systems on respective thematic areas. CEA servers are at the centre of EIS system. When completed, EIS will serve users from various institutions as well as from the general public. The EIS consist of:

- Environmental databases; environmental data collected and processed in accordance with the law and other regulations (environmental pollution register, environmental monitoring records, inventories of protected plant and animal species, records on movement of hazardous waste, databases on water quality, etc.).
- Scientific and thematic data; relevant expert and scientific data from national, foreign and international institutions and organizations; methodological and documentation data.
- Legal framework; texts of environmental regulations, policy plans and programs.
- Environmental reports; produced for various needs-from international and national policy obligations to specific thematic reports.

**Distributed databases:**

| | | |
|---|---|---|
| On-line data exchange, links between SQL server (within CEA) and external databases with relevant external institutions (stakeholders) | ⟶ | Internet connections |
| Access authorization with various security levels | ⟶ | Authorized access |
| GIS technology used for data presentation, querying and analysis | ⟶ | Use of WEB GIS technologies for data presentation and individual spatial data analysis |

As presented above, the EIS is envisaged as an integrated distributed information system where the server of the CEA is the central hub and other information modules (in and/or outside the CEA) make a network of clients. The entire EIS system is based on a Relational Database Management Systems (RDBMS) and the so-called *entity-relationship* model. The model itself is also dependent upon the topic area and comprises master data, whose structure throughout the analysis process should be defined, as well as complex tables that reference the master data by way of codes. Such a relational approach of data modelling via SQL (Structured Query Language) enables the realisation of basic functions of data processing in a relatively easy manner (data retrieval from the database, insertion of data into the database, alteration and deletion of data, and the formation of complex reports via SELECT statements). Thereby most of the needs of EIS are covered. Apart from obligatory reporting, the system also has mechanisms to enable the production of user defined reports.

Apart from the above-mentioned qualities, RDBMS (Relational Database Management System) possesses a system for protecting data integrity (so-called Backup & Recovery), which increases the security and compactness of the entire system. The smallest unit of work is a transaction, and in case of a system crash, it is either executed completely or not executed at all.

Data use, from the user side, assumes basic knowledge of the Windows environment and basic knowledge of GIS clients. Public access is possible through internet browsers of the newer generation (Extensible Markup Language – XML compatible). Data services are organised by the use of Microsoft SQL server (data level approach), ArcSDE server (application level approach) and ArcIMS server (Internet approach). RDBMS relations between tables are further strengthened by referential constraints (primary & foreign keys), with which the consistency of data is assured.

## V.2 Developed databases

### V.2.1 *Risk and Potentially Risk Installations Inventory*

In 2004, based upon a request of the Croatian Government, the Agency started the development of the Risk and Potentially Risk Installations Inventory as an integral part of the EIS.

- Inventory includes all risk installations at the Croatian territory and list of all relevant information: contact, service, type and quantity of dangerous substance (production, storage, processing, transport, collection or other activities), location description, protection measures and responsible person in case of accident and other information.
- The primary objective of this inventory is to facilitate efficient public authorities operations by providing them with a tool for monitoring of operation of all risk installations by the responsible inspections, and enable timely and efficient response in case of an accident.

The Internet-based application was developed to work with the inventory. It allows users direct access from remote locations and simple or advanced searching of the inventory. Data entry into the database (stage 1) has been finished. Currently the data on 78 entities and 151 sites/facilities are available.
The original database application was upgraded in 2006, with web-GIS interface that enables users to conduct spatial analysis for each location, and combine all relevant data from other georeferenced databases that are available through EIS.
Risk and Potentially Risk Installations Inventory is available at Agency web site [www.azo.hr] by username and password.

### *V.2.2 Environmental Emission Register*

Environmental Emission Register includes data on individual and collective pollutants, list of methods and purification devices, data on pollution emissions into air, inland water and sea, and landfill data:

- **Environmental Emission Register – air**. Database consist of data on emissions into air from industrial plants (non-energetic resources), energetic plants (direct combustion for purpose of process technology), thermal power plants and emissions into air for heating purposes (hot water, steam). Emissions into air are monitored in forms of inorganic gases, organic gases and vapour, and dust.

- **Environmental Emission Register – water/sea**. Database consist of data on quality of rivers, lakes and groundwater, water quantity, drinking water quality, inland bathing water quality, data on accidents, data on pollution caused by river traffic, wastewater and wastewater treatment plants data, and data on water/sea polluters. In order to improve quality of data on wastewater in Croatia, additional data were collected on availability and operation of urban wastewater and, partly, industrial wastewater treatment plants.
- **Environmental Emission Register – waste data**. Database contains data on annual waste types and quantities produced, collected, recovered or disposed. Data are delivered once a year by waste producers, authorized collectors and waste cultivators.

### *V.2.3 Environmental Information System – Marine*

Marine and coast protection information system development continued through the ASEMP Project (Adriatic Sea Environmental Master Plan). The project is focused on further creation of a marine information system (containing the data on sea, coastal zone, fisheries and aquaculture) and on development of application that will enable access to the available data to all interested users. Different access levels are planned and direct data entry by the data source. The project will develop and enable a web-site access to numerous additional data (environmental data, maps, spatial plans, population density, and coastal build-up) and instructions for sustainable planning and management of the Adriatic environment. The relevant data entries into the marine information system are carried out in collaboration with key institutions in the field.

### *V.2.4 Waste Management Information System*

Waste Management Information System (WMIS) integrates data on licensed waste operators, laboratories accredited for waste analyses, existing waste management plans, trans-boundary movement of waste, and other data posted on the Agency web site. Since 2005, the Agency also assumed the responsibility for keeping record of the waste register within Environmental Emission Register (EER/waste) which contains data on quantities of generated, collected and treated waste by kinds of waste. The waste register data for the previous years were sorted out, and reports on the analysed periods prepared.

### *V.2.5 Landfill cadastre*

As the first georeferenced (GIS) database of 283 landfills in Croatia, Landfill cadastre was finished in 2005, complete with landfill polygons for each location, image database, and all relevant data on processed landfills: general data (name, contact, landfill size, source of waste, quantity of stored waste), data on licences and documentation, waste types, location description, technical equipment on landfill, environmental protection measures on landfill, financial structure of rehabilitation. Landfill cadastre is available at Agency web site [www.azo.hr].

### *V.2.6 Croatian Environmental Projects Database*

The database on the environmental projects in Croatia is an integral part of the Agency's Environmental Information System. The database creation was initiated in order to collect the data on all ongoing or planned environmental projects with aim to improve planning of new projects, improve access and availability of the information to the professional community, public authorities and general public, and to reduce overlapping and/or duplication of the environmental activities. Currently 443 projects are reported in the database, of which 22 covering biological diversity, 14 forestry, 61 water, 42 marine, 44 soil, 10 energy, 67 air, 165 waste, and another 18 projects are covering different environment-related topics. This database is accessible to the general public on the Agency web site [www.azo.hr].

### *V.2.7 Database on Forest Ecosystem Stability and Damages*

Database contains data for the network of plots in 16×16 km grid at whole territory of Republic of Croatia. ID card for each plot (about 100 plots) is structured the following form: soil type, pedological and geological structure, coordinates in Gauss-Kruger system, hydrological and climate state, main types of plants and plants society, geo- Inclination, exposition etc. The database is completely coordinated with ICP protocol (International Cooperative Programme within the LRTAP convention):

- ICP forests Level I – Damage of crowns condition index of mortality, defoliation and discoloration.
- ICP forest Level II for main three species – contains of heavy metals in soil and plant organs.

The data included in the database are from period from 1987 to 2004. Database web interface development is in progress.

#### *V.2.8 Database on researches of biodiversity components in designated areas*

The database relying on results of biodiversity research conducted in protected areas is being developed, and the data on population of indigenous breed species are also being collected. Database contains the most important data on nine protected area designations in Republic of Croatia: borders and boundaries, coordinates, names, categories of protection, International Site Code, International Union for Conservation of Nature (IUCN) code of protection, data on designation (year, low act etc.), name of researching field and projects which are going on, form of project results (GIS, research papers, web pages), data on responsible institution for each project (metadata), data on species diversity in all taxonomic groups. Included data are for period from 2000 to 2006. Database web interface development is in progress.

#### *V.2.9 Databases under development*

Listed below are databases under construction:

- **Air quality**
- **Climate Change**
- **Ozone Layer Protection**
- **Stability, damages and trends in forest ecosystem**
- **Database on genetic resources and forest species seed locations**
- **Metadata on biodiversity components research and projects in designated area**
- **Database on endemic flora and fauna species of Croatia**
- **Adriatic Sea Environmental Master Plan – ASEMP**

## V.3 Croatian Soil information system (CROSIS)

#### *V.3.1 Present State*

There is no systematic collection of data at the national territory. In addition, proscribed forms or national standards that can assure compatibility of methods and data dissemination do not exist. Soil data available in Croatia have been mainly collected for scientific, research and professional purposes in producing different-scale maps for planning and/or designing agro- and/or hydro-amelioration works, soil protection from erosion, pollution and damage, soil fertility control and reclamation projects. Croatia has no integral space-time georeferenced soil information database. Soil data are collected by different institutions within scientific and/or applied soil surveys. Methods used for collecting data are mostly not comparable to dissemination procedures and are stored on different media – printed, maps and partly digital forms.

Most methodologically uniformed data, but not georeferenced, were obtained by semi-detailed mapping of Croatian territory and production of the Basic Soil Map, scale 1:50,000. Typological, morphological, physical and chemical characteristics of soils are described in about 5,000 soil profiles. Even more soil profiles, not systematized, exist within detailed soil research projects for the specific needs; soil use planning, remediation of polluted soils as well as for the needs of physical planning, stored in various researches and designing institutions (Husnjak et al., 2006). Also, the majority of historical data are not stored on digital media (data are scattered in hardcopy materials), so there is a potential risk of losing information despite availability of some data.

#### *V.3.2 Policy Background for CROSIS development*

CROSIS, as a part of European Information Service Centre (EISC), is considered to be one of the most important instruments for setting up a sustainable land management practice in agriculture and forestry of Croatia, as well as implementing the environmental protection policies; planning the soil protection strategy, a soil protection act and other relevant action planning. National Environmental Strategy, National Environmental Action Plan (Official Gazette 82/1994, 74/1999), information structure of the future **Environment Information System of Croatia (EISC)** and international commitments, including the UN Convention to Combat Desertification (Official Gazette – International Contracts 11/2000, 14/2000) point to the need of monitoring the pressure, state and response of soil indicators as the basis for development of strategies and soil protection programs, including mitigation of drought effects. These tasks are in line with present accession activities whose aim is harmonisation with EU policy.

### *V.3.3 Activities*

CEA, with EC financial support through LIFE Third Countries Programme, started a project called "**Development of the Croatian Soil Monitoring Programme with a Pilot project**" (SMP), as the base for development of Soil Monitoring System which will provide harmonized methods and standards for soil sampling, analysis, display and dissemination of data and assure data compatibility at national and EU level. The project has started in January 2006, with expected duration of three years. SMP will be tested by the Pilot projects on agricultural and forestry soil, and contaminated sites, with aim to provide information on feasibility, and to remove and/or improve eventual wrong approach and steps in implementation of soil monitoring in Croatia. Expected results of the project are:

- Development of database and list of existing soil, air and water monitoring stations and spots, and their coordinates Proposal of National soil monitoring stations and spots with coordinates for agricultural land, forestry land and contaminated sites
- Proposal to relevant institutions for conduction of National Soil Monitoring Programme
- List of recognized reference centres for gathering and analysis of provided data
- Proposal of financial structure for covering of the soil monitoring network costs

Beside the SMP project, CEA has focused on developing overall and unique information system with aim to assure data flow. At the moment, the system consist of soil map of Republic of Croatia (1:300,000), regional studies and databases of counties of Karlovac, Slavonski Brod-Posavina, Sisak-Moslavina, Vukovar-Srijem, City of Zagreb and County of Zagreb, and County of Virovitica-Podravina. CROSIS, as a part of the Environment Information System of Croatia (EISC) is considered to be one of the most important instruments for the creation of sustainable soil and land management practice in agriculture and forestry, as well as placing the environmental protection policies into effect; planning and monitoring the implementation of Soil protection strategy, Soil protection act and other relevant actions. The Soil Monitoring System is the base for development of harmonised and coherent Croatian soil information system, compatible with the European Soil Information System – EUSIS, crucial for policy-makers, other users and international communication. This refers both to the current status and to the indicators of future changes of soil state.

**CROSIS implementation and maintenance** is planned to be organized within the CROSIS Reference Centre, as the thematic-operational unit of the Environment information system of Croatia, including the attributes defined by the European soil database – European Soil Information System (EUSIS), which will ensure its compatibility in exchanging data with the European Union authorities. Also, CROSIS should be conceived in such a way as to ensure required data and information for state administration bodies, primarily the Ministry of Environmental Protection, Physical Planning and Construction, the Ministry of Agriculture, Forestry and Water Management, the public institutions in protected areas, the local government and self-government bodies, e.g. county departments of environmental protection and agriculture. Data accessibility to the public will be provided via the Internet interface of the CEA, with special controlled levels of information accessibility depending on the group to which stakeholders belong.

**The polygon-based information layer** – soil map at the scale of 1:250,000 covers the entire territory of Croatia. Georeferenced database of soil profiles, composite and individual soil samples, with all typical characteristics, georeferenced database of soil pollution, damage and degradation samples make up the point information layer, which has inter- and multidisciplinary uses. CROSIS belongs to the first full-scale application category. The above-mentioned databases constitute the initial source of information for the development, use and protection of soil, as an unrecoverable land resource, and a vulnerable environmental element. One of the first planned activities is a building of database and various layers:

A) Polygon information layers – soil map, scale 1:250,000

B) Point information layers:

- Georeferenced soil profile data
- Georeferenced soil samples data (average and individual)
- Georeferenced soil pollution data
- Georeferenced soil damage data
- Georeferenced soil degradation data

## V.4 Established databases

Besides the previously mentioned activities, certain databases relevant for CROSIS functionality are already developed and publicly available at CEA web site.

### *V.4.1 Potentially polluted and polluted sites database – GEOL*

This database contains geo-referenced information and data about potentially contaminated and contaminated sites, remediation activities, reporting track records and the data set on subjects that caused the pollution. The database was completed in 2006, and it is relationally linked with *Landfill cadastre* and *Risk and Potentially Risk Installations Inventory* databases.

The development of the GEOL database is in accordance with requirements of *National Environmental Strategy* (OG 46/02), and the *Guidelines for EIONET data collection on contaminated sites.* The GEOL provides information and data about *potentially contaminated and contaminated sites, remediation activities*, and to provide data received by *monitoring of remediate sites.* Information and data will be available for public at the *CEA web* in the near future. Access is secured through special control levels (general public, stakeholders, loading of data, IT service support).

**Table V.1. Number of potential and contaminated sites by categories (2005, Source CEA).**

| | | *Potential polluted sites* | | *Polluted sites* | | *Remediate* | |
|---|---|---|---|---|---|---|---|
| No. | Main types of localized source | Total No | % | Total No | % | Total No | % |
| 1 | Municipal waste disposal sites | 276 | 24.0 | 0 | 0.0 | | 0.0 |
| 2 | Industrial waste disposal sites | 1 | 0.1 | 2 | 5.3 | | 0.0 |
| 3 | Industrial and commercial sites | 224 | 19.5 | 5 | 13.2 | | 0.0 |
| 4 | Formal military sites | | 0.0 | | 0.0 | | 0.0 |
| 5 | Mining sites | 173 | 15.0 | | 0.0 | | 0.0 |
| 6 | Oil extraction sites | | 0.0 | | 0.0 | | 0.0 |
| 7 | Oil storage sites | 439 | 38.1 | | 0.0 | | 0.0 |
| 8 | Oil spills sites | 24 | 2.1 | 24 | 63.2 | 21 | 80.8 |
| 9 | Power plants | 8 | 0.7 | 2 | 5.3 | 2 | 7.7 |
| 10 | Storage of manure | 1 | 0.1 | | 0.0 | | 0.0 |
| 11 | Other hazardous substances spills sites | 5 | 0.4 | 5 | 13.2 | 3 | 11.5 |
| 12 | Other | | 0.0 | | 0.0 | | 0.0 |
| | **Total** | 1151 | 100.0 | 38 | 100.0 | 26 | 100.0 |

Main GEOL users are government bodies; especially the Ministry of Environmental Protection, Physical Planning and Construction, the Ministry of Agriculture, Forestry and Water Management, the public administration and local government, general professional and scientific community. The GEOL consists of:

- **Sources of contamination** (recognized and potential); Municipal and industrial waste landfill, industrial and commercial localities *(energy production, oil industry, chemical industry, metal production, electronic production, glass, ceramic and stone production, textile, leather, wood and paper industry, food industry), mining sites and surface excavation (i.e. quarries),* former military sites and storages, oil extraction and storage sites, oil spills sites, power plants, mining sites, storage of manure and other pollutant spill sites.
- **Pollutant register**: phenols, heavy metals, chlorinated hydrocarbons (CHC), polycyclic aromatic hydrocarbons (PAH), cyanide, mineral oil, aromatic hydrocarbons (BTEX) etc.
- **Status of recognized contaminated sites**: contaminated site management, existence of preliminary study, research, level of implemented remediation, existence of monitoring, and remediation costs (state budget and private).

Based on available data, there were 1151 potentially polluted sites in 2005, out of which 38 polluted locations were declared positive (Table V.1, Fig. V.1). Local contamination occurs at intensive industrial activity areas, inapt landfills, mineral extraction sites, military areas or as a result of different accidents (Fig. V.2). These cases are mostly connected to landfills and to accidents, such as oil pipeline rifts, traffic accidents etc. It is assumed that number of potentially polluted sites is not final and actual number of polluted sites and locations still needs to be investigated.

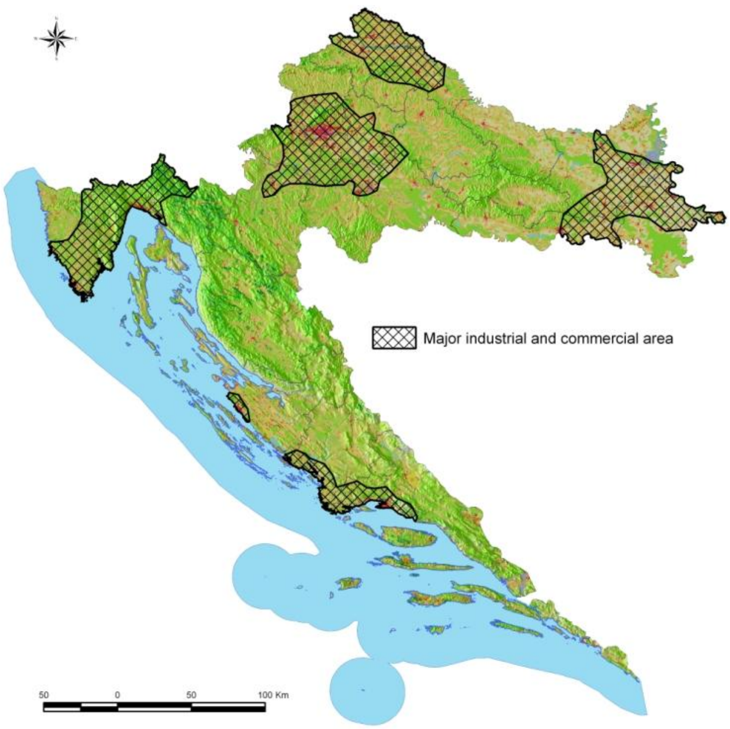


**Fig. V.1: Potentially polluted sites; major industrial and commercial area (Source: CEA).**

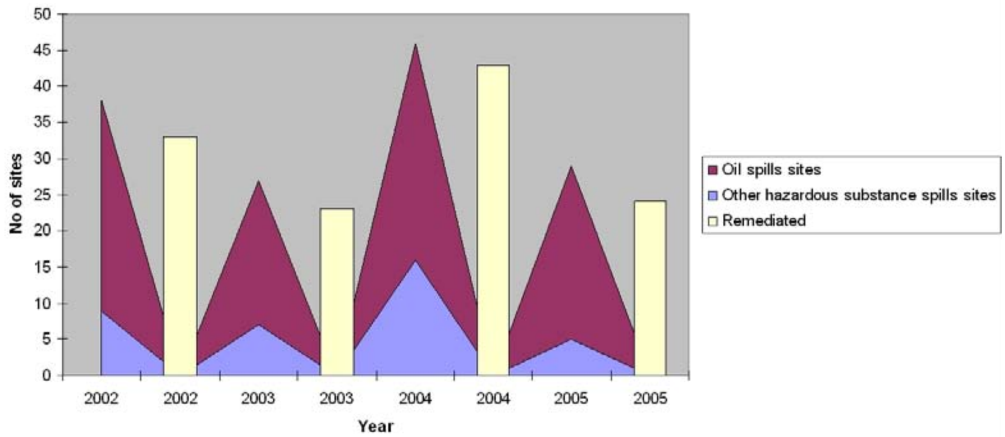


**Fig. V.2. Local site pollution by traffic accidents 2002-2005 (Source: CEA).**

### *V.4.2 Corine Land Cover – CLC2000*

The CORINE Land Cover[4] 2000 – Croatia (CLC2000-Croatia) database is an outcome of a project launched by the Ministry of Environmental Protection, Physical Planning and Construction in 2002. GISDATA and OIKON companies participated in the project implementation, and it was co-financed through the LifeIII program. CLC 2000-Croatia is a digital database, homogenous and consistent with the land cover data in the entire European Union. CLC 2000-Croatia is based on photointerpretation of satellite images made by national teams of the participating countries. The national inventories of the land cover comprise the European land cover map. The Ministry of Environmental Protection, Physical Planning and Construction has decided to appoint the Croatian Environment Agency as referent institution for the Corine Land Cover. Since December 2005,

[4] *CORINE (COoRdination of INformation on the Environment) is a program initiated in 1985 by the decision of the European Commission aiming to insure consistent information on the state of the environment and nature in the European Community. In 1991, the European Commission decided to expand the inventorisation of the land cover using the CORINE methodology on the CEE countries through the Phare program.*

the professionals and general public have access to the CLC on the Agency web site – [www.azo.hr] – with possibilities to make a simple queries and list sub bases: Land Cover (for years 1980, 1990, and 2000), Land Cover Changes (1990/2000, 1980/1990 and 1980/2000). Also, Satellite Images (1980, 1990 and 2000) and Satellite Charts (1980, 1990 and 2000) are available.

The Agency has also initiated the CLC database updating with the land cover data for 2005-2006, and the development of detailed layers for urban zones for the years 2000 and 2005. According to data from all three databases, we have come to conclusion that the highest portions of land in all three datasets are occupied by following classes:

- Class 311 – broadleaved forest ( 30.1 %, 29.9% and 29.8% in years 1980, 1990 and 2000)
- Class 242 – complex cultivation patterns (18.3 %, 17.9% and 17.7%)
- Class 324 – transitional woodland/shrub (10.0 %, 10.5% and 10.6%) .

All other classes are below 10% and changes in their areas do not reflect general trends. In order to detect general trends, classes are grouped in similar categories: land cover classes are grouped into seven categories and then compared (Fig. V.3). It is visible that the areas of intensive human influence (settlement and traffic network expansion) are increasing as well as the inland waters and marshes (accumulation).

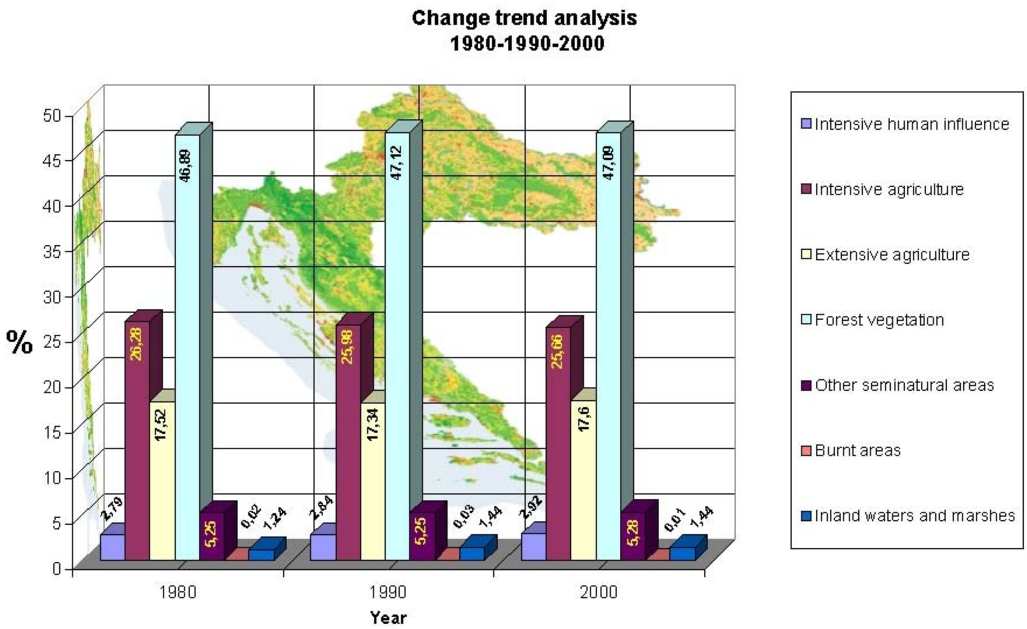


**Fig. V.3. Change of trends throughout the years 1980-1990-2000 (Source CEA).**

The difference in trend of changes from 1980 – 1990 and 1990 – 2000 is visible in classes *extensive agriculture* and *forest vegetation*. That means that artificial areas (settlements, accumulations of water, traffic network etc) are increasing. According to sub indicators, calculated by using of LEAC methodology (ETC/TE), during 1990-2000, 4,587 ha (459 ha per year) of land were permanently changed to artificial surfaces (Fig. V.4). Main driver of land uptake by artificial development is house building, services and recreation areas with 2.424 ha. Second driver for increase of the size of urban and other artificial areas is the sprawl of industrial and commercial sites with 1.230 ha of permanent land uptake. Building of transport networks and mines quarrying areas are responsible for land take with 492 and 441 ha accordingly.

During 1990-2000, the main permanently-changed category was *Pastures & mosaics of agriculture land* (CORINE Land Cover Aggregated nomenclature for LEAC), where 74.3% (3338 ha) of total land changed (Fig. V.3). 373 ha was taken from the category *Pasture*, and 2965 ha from the category *Complex cultivation patterns*. 1051 ha or 23.4% of total land uptake was taken from category *Forest land*, 584 ha from category *Standing forests*, and 467 ha from *Transitional woodland & shrub*. From category *Arable land & permanent crops* 83 ha was taken which is 1.9% of total land uptake. The lowest land uptake was for *Semi-natural vegetation*, where only 20 ha (0.5%) was taken.

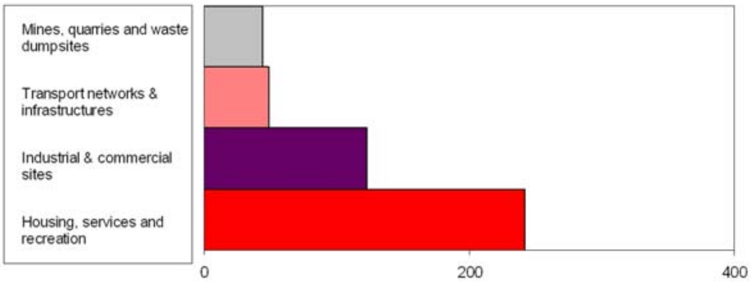


**Fig. V.4. Main Land takes drivers in period 1990-2000 in ha/year (Data Source: CEA).**

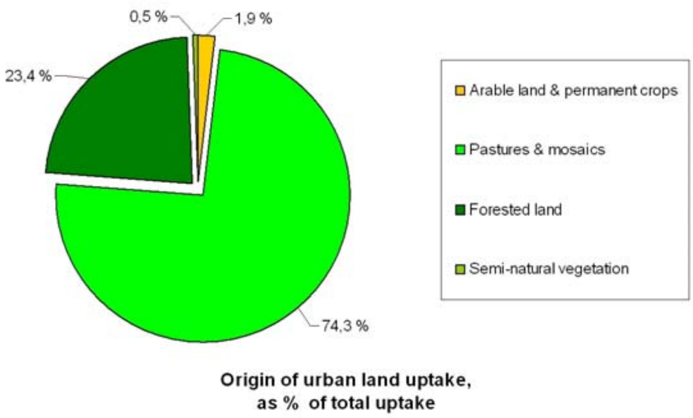


**Fig. V.5. Origin of urban land uptake as % of total uptake in 2006 (Data source: CEA).**

### *V.4.3 Soil and Plant Laboratories database*

The Soil and Plant laboratories database was developed between November 2004 and January 2005 and it is regularly updated, in cooperation with Institute for Soil in Osijek. The database has a purpose to identify and consolidate existing information about laboratories that conduct soil and plant material analysis. The database contains a list of existing soil and plant laboratories (21 laboratories are included at the moment) with contact information, employee's structure, equipment data, samples handling procedures, certification data, conducting analysis, used methodologies, hazardous waste management, etc. The Soil and Plant Laboratories database is available for general public at [http://baza.azo.hr/projekt_lab/]. A standard form is also available on line for updates and changes of existing data.

## V.5 Conclusion

Technically speaking, all necessary institutions and experts in Croatia are already available. From this side, there are no obstacles to develop a proper and internationally compatible Soil information system. The mentioned activities taken so far can be considered as valuable and focused in a good direction. However, without political back-up; legislation in place and proscribed duties and responsibilities, those activities can not be finished on time. The future destiny of Croatian Soil Information System needs to be followed and supported by Government in order to assure data flow and data management system supported by financial and institutional framework.

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# VI. Overview of soil information and soil protection policies in the former Yugoslav Republic of Macedonia

Margareta Cvetkovska[1], Tatjana Mitkova[2], Josif Mitrikeski[2], Svetlana Gjorgeva[1], and Mile Markoski[2]

1 Ministry of Environment and Physical Planning
Drezdenska 50, 1000 Skopje, Republic of Macedonia
Tel.: + 389 02 3066 930; Fax: + 389 3066 931
M.Cvetkovska@moepp.gov.mk; kalimar@mt.net.mk; S.Gjorgeva@moepp.gov.mk

2 Faculty of Agricultural Sciences and Food
bul. “Aleksandar Makedonski”, 1000 Skopje, Republic of Macedonia
Tel.: + 389 2 311 52 77, Fax.: + 389 2 313 43 10
tmitkova@zf.ukum.edu.mk; jmitrikeski@zf.ukim.edu.mk; mmarkoski@zf.ukim.edu.mk

**Summary**

*In the domain of soils information and soil protection policies in Republic of Macedonia, the main priorities include the upgrading of legislation on soil as environmental medium; overcoming of pollution from local industrial and commercial sources and municipal landfills, as well as transboundary air pollution; prevention of uncontrolled land use change in urban areas. Great attention needs to be devoted to land erosion control in the Republic of Macedonia, which is one of the most endangered countries in the Balkan Peninsula in this regard, as well as to identification of funding sources for reclamation of historical soil contaminations due to the operation of mines in eastern parts of Macedonia and industrial facilities. The report in addition presents: natural characteristic, land use, types of soil degradation, identification of problems and priorities, present protection policy, and finally objectives and future prospects for soil resources in Macedonia.*

## VI.1 The general context

The Republic of Macedonia is a land-locked country, situated in the central part of the Southern Balkan Peninsula. The country is among the smallest in Europe, bordering four states. Topography of the country is characterized by big and high mountain massifs. Its territory is mountainous, crossed through with river valleys (Fig. VI.1). The average height is 850 meters above the sea level. The River of Vardar cuts through the entire country. Most of its total length is in Macedonia, and the rest is in Greece. The country has three big tectonic lakes, 15 artificial lakes and 25 glacial lakes (Environmental Performance Reviews, 2002).


**Fig. VI.1. Republic of Macedonia, population: 2,022,547 inhabitants, area: 25,713 km$^2$.**

Macedonia is small in size (25,713 km$^2$). About 80% of the territory is located in the hilly-mountainous and mountainous region (Table VI.1). The whole territory of Macedonia is divided in 8 soil-climate-vegetation zones (Filipovski, 1996). The soil cover is very heterogeneous, which means that it changes within small distances.

**Table VI.1. Total surface area in km$^2$ and natural complexes in the Republic of Macedonia.**

| *Type* | *Surface in km$^2$* | *%* |
|---|---|---|
| Water surfaces | 488 | 1.9 |
| Plain terrains | 4900 | 19.1 |
| Mountain terrains | 20,325 | 79.0 |
| **Total:** | 25,713 | 100.0 |

Although small in size, Macedonia is characterized by high number of soil types, i.e. more than 30, thus representing a natural museum of almost all soils found in Europe (Filipovski, 1995). According to Corine Land Cover 2000, dominant type of land cover in Republic of Macedonia are: forest and semi natural areas (60%); agricultural areas (37%); artificial areas (1%) and water bodies (2%). Only 36% of the land in Macedonia is located in valleys. Half of Macedonia's territory (50.8%) is used for agriculture, almost equally divided into arable land and pastures. Only 7% of arable land is highly fertile.

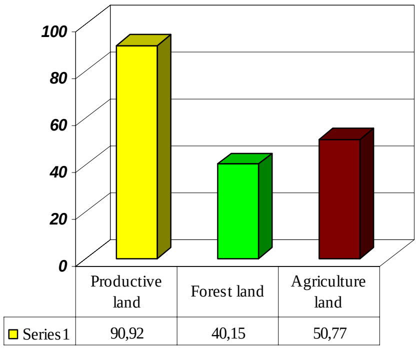
There are eight climate, vegetation and soil areas: Sub-Mediterranean area, with an average annual temperature of 14.2°C; Continental-Sub-Mediterranean area, with an average annual temperature of 12.7°C, and average precipitation of 500 mm; Warm continental area, with an average annual temperature of 10.9°C and average precipitation of 700 mm; Cold continental area, with an average annual temperature of 9°C and average precipitation of 850 mm; Sub-hilly continental-mountainous area, with an average annual temperature of 8°C and average precipitation of 900 mm; Hilly continental-mountainous area, with an average annual temperature of 6.4°C and average precipitation of 1044-1103 mm; Sub-Alpine mountainous area, with an average annual temperature of 4.8°C and average precipitation of 1000 mm; Alpine mountainous area, with an average annual temperature of -0.4°C and average precipitation of 800 mm, (Filipovski et al. 1996).

**Fig. VI.2. Mountain Galicica, and part of Ohrid lake.**

The whole area is divided in 4,255,091 parcels in 1714 cadastre municipalities. The average size of a parcel is 0.6 ha. Land use distribution in the Macedonia (in %) and land distribution by bonity classes in % are given in Fig. VI.3.

Considering the land use dynamics, the following trends can be distinguished:

- Around 10% of the territory is classified as unproductive land;
- Only one-half of productive land is arable. This represents one-fourth of the territory. Part of the arable land has been abandoned, thus comprising one-fifth of the territory.
- Only 8% of the arable land belongs to the higher land use classes. The reduction of the arable surfaces continues in its most fertile sections as the result of different types of degradation;
- With the different types of changes made in the use of lands described above, around 70,000 hectares, most of which is first class land, have been extracted from agricultural production.



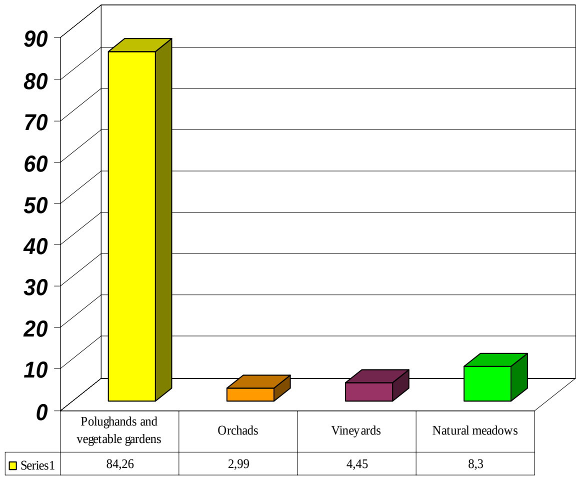




**Fig. VI.3. Land use distribution in the Republic of Macedonia (in %): (left) total productive land, (right) agricultural land.**

**Soil Map of Macedonia** exists as a draft version in hard copy. This coverage encompasses 56 sheets, part of which are out of data and need revision. Main constrain is that the map and the alphanumerical data are not stored in appropriate conditions and format and might be lost. In addition, if the map will not be elaborated in an appropriate format, the data can not be used to produce different thematic and risk maps. For the above mentioned reason, the Soil Department of the Institute of Agriculture in collaboration with the Soil Department of the Faculty of Agriculture and Food, as the main two authorized entities of these data, have already prepared two project proposals within the FP6 an CADSES[5] Inter region program in order to pave the way towards elaboration of the existing soil data.

## VI.2 Threats against soils

### *VI.2.1 Diffuse contamination*

Potential pollution of our soils with acid rains may be of different origin, such as from thermal power plants in our country, as well as in neighboring countries, like Greece, Bulgaria and Serbia, but also from the whole Europe (Filipovski, 2003). Contamination is the strongest and most frequent with lead, cadmium and zinc, in the vicinity of mines in north-eastern parts of Macedonia (Zletovo, Toranica, Sasa), as well as in the central part of the country (smeltery in Veles), and it is rarer and weaker with copper, chromium, nickel, arsenic, mercury, iron and manganese (Filipovski, 2003).

Soil pollution alongside highways in Macedonia is higher than in other unpolluted soils, but lower than in Skopje. This refers primarily to zinc and lead. In surface layers (0-20 cm), there is stronger accumulation of lead and zinc and descendent movement of these elements is weak (Filipovski, 2003).

There is soil pollution with nitrates, phosphates, sulphates, pesticides, organic pollutants, heavy metals, oil, but there is no established regular and long-term soil monitoring system. It is important to mention pollutions from agriculture; municipal waste and industrial and hazardous waste. The research that has been carried out so far indicates that the quantity of heavy metals in agricultural soil is not above maximum available concentration (MAC), with the exception of the soil and plants in the vicinity of several 'hot spots', such as the metallurgical facilities (e.g. Veles) where pollution occurs through air or is caused by the flotation material from the mines (Zletovo, Sasa, Toranica). The measurement of the quantities of heavy metals (lead, zinc, copper) in the soil and plants in the urban area of Skopje, Veles shows that there are sites where the values of these heavy metals are above the MAC. The analyses of the soils near motorways show increased quantities of lead, zinc and cadmium.

In the agriculture in average about 25,000 tones of mineral fertilizers are used annualy, 48,000 tones of nitric fertilizers, 3,000,000 tones of organic fertilizers. No figures are available from the research of the harmful effects of the excessive doses of certain mineral fertilizers on the soil (especially the nitrates), on ground waters and on the quality of plants [www.soer.moe.gov.mk]. The researches of soils contamination in Macedonia with residues of pesticides and radioactivity are very modest (Mitrikeski J., et.al. 2002).

[5] CADSES region: Central European, Adriatic, Danubian, and South-Eastern Space.

### VI.2.2 2.2. Hydro-geological risks

Soils may be polluted by contaminated surface and ground waters in case it comes into contact with them in any way. Due to the developed drainage, i.e. protection against flood of an area of close to 70,000 ha, contaminated river waters can not come into contact with soil through floods. Exceptions from this include several hot-spots, i.e. soils along rivers carrying polluted wastewater from mines in the eastern part of Macedonia. Areas of soils around the rivers Zletovo, Kamenica and Toranica are not protected against floods (Filipovski, 2003).

In Macedonia, 106 land reclamation systems and around 20 major accumulations have been constructed. Irrigation network of 140,000 ha has been developed, with an optimum irrigation capacity for 126,000 ha, but in reality, different land areas of 80,000 ha are irrigated. Most of the land areas irrigated from artificial accumulations are located in upper course of the rivers, above the sources of pollution, except accumulations of Tikves and Kalimanci. The most polluted (especially with heavy metals) are the waters used in mines (Zletovo, Sasa, Toranica), in flotation processes. Soils irrigated with river waters enriched with effluents, are polluted with heavy metals, especially lead and zinc (Filipovski, 2003).

### VI.2.3 Reduction of organic matters

Originaly, it is estimated that 95% of Macedonia's territory was under forest, and only a small portion was under natural grass vegetation before the commencement of destruction and degradation of natural vegetation and conversion of natural soils into agricultural land. Only slightly above 1/3 of natural forests have been preserved. Half of destructed forests have been conversed into pastures, and half into arable land areas, and bare areas have expanded as well (337,000 ha). A significant component of the above soil degradation is the reduction of plant residues, humus and biogenic elements and decrease in natural soil fertility (Filipovski, 2003).

Reduction of humus by meadow and swamp vegetation tilling in Pelagonia, one of the largest ravines in Macedonia used for cultivation of different agricultural crops, is as follows: contents of humus in meadow soil prior to tilling 3.98%, after tilling – 3.43%, while in swamp soils – 6.32% and 5.29%, respectively. This indicates that around 15% of the total quantity of humus have been lost during a period of 20 years. In Pelagonia, 0.75% of the total quantity of humus is lost every year, which means that biological degradation is low, i.e. below 1%. The average content of humus in Macedonian soils, by specific soil types, is as follows: rendzinas in mountainous areas (11.3%); vertisols (4.17-4.68%), brown forest soils (4.6%), alluvial soils (2.9-3.9%) (Filipovski, 2003).

The status of agricultural land humization is unfavourable. Ploughed fields contain, at an average, half percent humus less than non-arable land. Such unfavourable status of agricultural land humus content has resulted from the long period of uncontrolled intensive agrotechnics use and over-use of the soil in the past. There are partial researches in order to assess the present condition for soil improvement; to assess the fertility or to investigate the loss of nutrients by erosion. The data is not complete so it is not representative for the whole territory.

### VI.2.4 Erosion

Land erosion is a process of soil degradation and its deposition in the lower areas of a watershed. In our country, water erosion is dominant type of erosion, especially the one caused by rain falls and running waters. Aeolian erosion is present in higher mountainous areas, but damages resulting from it are minor compared to the ones caused by water erosion. The same is also a case with the abrasive erosion caused by lake waves in the country (Filipovski, 2003).

Macedonia is one of the most endangered territories on the Balkans, in terms of erosion. This is due to the following reasons:

- Long lasting destructive impacts from man (destruction of natural vegetation, absence of measures for agricultural land conservation, improper cultivation leading to deterioration of physical properties of soils).
- Relief in which mountains and valley alternate, involving sloppy and long inclinations.
- Liability to erosion in certain sediments, rocks and soils.
- Climate conditions, such as torrent nature of rain falls, climate aridity resulting in weaker coverage of soil by vegetation, and renewal of destructed vegetation is more difficult.

There are around 1700 torrent currents in our country, covering an area of 18,229 km$^2$ (71% of the whole territory). These torrents are divided into five categories of torrential strength, where the first category has the highest coefficient of torrential strength. The first three categories (excessive, strong and medium-strong erosion) require undertaking of protective measures. These categories make up to 52.3% of the total recorded torrential area or 37% of the territory of the Republic of Macedonia (Filipovski, 2003; Fig. VI.4).

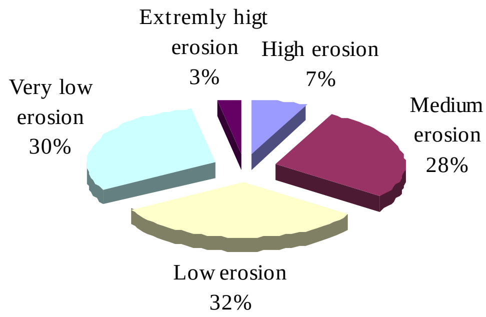



**Fig. VI.4. Distribution of soil erosion in Republic of Macedonia in %.**

Soil erosion remains the principal type of soil degradation: ca. 22% of the surfaces of all soils are formed under the influence of erosion, and around 38% of the territory is exposed to more intense erosion. Soil erosion is the dominant type of soil degradation. According to the Erosion Map (1992), 96.5% of the total area of the country is under processes of erosion (Blinkov et.al. 2000). The map is prepared on a basis of assessment by the Gavrilovic methodology, and it is necessary to abdate. A “Map of risks from erosion” should also be prepared, for planning of the agriculture, forestry and water economy development.

Natural conditions as well as inadequate practices in arable farming, grazing management and deforestation in the past have contributed to high rate erosion processes. Processes of water erosion are most dominant. According to the report of the European Environment Agency, Macedonia is placed in the so called "*red zone of water erosion in Europe*". Significant part of erosion deposits occur in natural lakes and reservoirs. Annual soil loss represents an annual average loss of arable soil layer of 20 cm depth on an area of 8,500 ha, which means 17,000,000 $m^3$ of soil are lost every year. They fill the natural lakes and artificial accumulations and bury fertile soils (Filipovski, 2003). The economic cost of erosion impacts is considerable.

### *VI.2.5 Contamination from local sources*

One of the methods of exploitation of coal, copper and nickel ores in Macedonia, is by open pit excavations. Major damages appear during the exploitation of coal for energy production, because it is found in our ravines below fertile soils and below deep layers of loose sediments. These open pits destroy soils and lead to creation of large quantities of thrown sterile earth (geological layers above the coal layer). Such is the case of coal mines Suvodol in the area of Bitola and Oslomej in the area of Kicevo (Filipovski, 2003).

**The solid waste** from mines with excavations of Fe, Zn, Pb, Cu, Ni, Cr and Sb (Zletovo, Sasa, Toranica, Bucim, Radusa and Lojane) contains heavy metals and it is processed by flotation. Flotation material in Zletovo, Sasa and Toranica is rich in Zn, Pb and Cd. Tailings disposal site at Bucim covers an area of 30 ha. Flotation material in the mine of Lojane, apart from chromium and antimony, contains significant quantities of highly toxic arsenic (Filipovski, 2003).

**Metallurgical waste** in the Republic of Macedonia is generated in smelting plants producing iron, steel and alloys (Steelworks-Skopje), lead and zinc (Zletovo-Veles) ferronickel (Fenimak-Kavadarci) and ferro-chromium, ferrosilicon and silicon metal (Jugohrom-Jegunovce). This waste, with its mass, covers certain area of productive land, thus reducing the land resources. This area is not known, but it could not be large, as the waste mass is relatively low, compared to mining. Major damage to soils and to the environment in general is posed by heavy metals contained in the waste, which then causes contamination of soils. Huge quantity of heavy metals is a result of the applied technology with low ore utilization rates. It contaminates the environment not only by heavy metals, but with other substances as well (e.g. organic pollutants) (Filipovski, 2003).

There is limited data on soil contamination with industrial waste in the country. This waste contains mainly persistent organic pollutants, chlorinated hydrocarbons, polycyclic aromatic hydrocarbons, phenols, cyanides, aromatic hydrocarbons, pesticides, etc. The main industrial polluters in the area include: OHIS-Skopje, Oil Refinery OKTA, Cement Factory, Tannery and Slaughter House – Skopje, celluloses and paper producing factory – Kocani, metal processing factory Zastava – Ohrid, "Tane Calevski" – Kicevo, plants for fertilizers production "Zletovo" – Veles (Filipovski, 2003).

Our **thermal power plants** generate huge quantities of waste in a form of ashes and slag, because they use lignite of low caloric value and high content of ashes. The ashes spread around with the wind that contains heavy metals, but also traces of uranium and thorium. The depot with ashes in the site of REK Bitola (thermal power plant) on fertile soil covers 10 ha (Filipovski, 2003).

**Municipal waste** is of heterogeneous composition and results from human activity. It is disposed on certain landfills, but also on illegal dumping sites in rural areas throughout the country. Apart from municipal waste, other types of waste, such as construction, industrial, hospital waste etc., are disposed on these landfills. In selecting the landfilling sites, no account was taken of relief, hydrographic, geological and soil conditions to be met in relation to the minimization of impacts on the environment. Landfills in the country cover an area of 200 ha, and soil burial leads to decline in productive land resources, but also there are damages in terms of soil contamination (Filipovski, 2003).

### *VI.2.6 Land use change*

Productive land resources in Macedonia have decreased through land use change, for example areas used for water accumulation, for development of new settlements and industrial facilities and construction of different infrastructure facilities, like highways, railways, etc. Migration from rural to urban areas in Macedonia have been present in Macedonia, leading to rapid urbanization, expansion of some settlements, without control being conducted over the type of land intended for development of certain facilities. In addition, many week-end settlements and tourist facilities have been developed. There is no accurate data on newly developed areas and land use change in Macedonia (Country study for biodiversity of the Republic of Macedonia, 2003).

According to data of CORINE LandCover 1990, around 1% of the area of our country is covered by continuous and discontinuous urban land, green urban areas, sport facilities, industrial and commercial facilities, roads, railways and airports, mines and landfills. Land use change has also impacts in terms of habitats fragmentation and disconnection of migration corridors of wild animal species. Demand for new buildings and for better transportation structure continues to grow in the Republic of Macedonia.

According to some data, about 0.5% of the agricultural soil is irreplaceable lost every year for construction of different infrastructural objects and urbanization (soil sealing). The surface of land reserves is reduced through destruction and the change of its use. Destruction is caused by open mines and excavation of various materials, as well as by covering the soil with different kinds of solid waste that comes from mines, metallurgical and other industrial facilities and urban solid waste. Land reserve surface is being used for building water accumulations, settlements, industrial and infrastructure fasilities. According to the old spatial plan (1981), it was predicted that the unarable area would increase from 151,905 ha to 188,111 ha.(by 12.4%). In adddition, in the new spatial plan (2000), it was planned that the unarable land would increase from 156,700 ha to 176,400 ha (11.3%). If these predictions are correct, by 2020 the arable area in our country will decrease from 176,400 to 156,700 ha as a result of the consequent conversion of the land.

In our country the deposited urban waste is ca. 20,500,000 cubic meters (6000 $m^3$ per year). There is only one waste material deposit that functions properly (Drisla in Skopje); however, the waste is not recycled and, therefore, covers the soil and pollutes the water and the soil (Filipovski, 2003). The most serious problems in the country are the pollution of surface waters (as a result of discharging untreated waste waters), and the inadequate treatment of the solid and hazardous waste.

### *VI.2.7 Aridification*

According to the climate indicators (temperatures, falls, sun isolation, moisture deficit, drought index) about 75.6% of the territory indicates signs of aridity or semi-aridity. With the global climate changes, it can be expected that this percentage will increase. This leads to desertification, decreasing of the forestation, loss of the bio-diversity, and increasing of the erosive processes. Unfortunately, there are no available data on land degradation and desertification in the country, despite erosion. Also there is no advanced research nor data at the research level. Thematic report on desertification is drafted within the Global Environment Facility (GEF) project for National Capacity Self Assessment (NSCA) defining activities to be undertaken in order to address the needs for capacity building on individual, institutional and system level (NEAP 2).

### *VI.2.8 Acidification, salinization and alkalization*

Due to climatic conditions and other factors related to soil acidification, this type of soil degradation is insignificant. Acidification is not examined at all. There are naturally acidic soils (brown forest soils). The forestation (100,000 ha) with coniferous species (Black pine; Arizona cypress tree), causes soil acidification. But it is better to have soil, even acidified, than the erosive processes to take it completely. There is no information on the harmful effect of acid rains on soil. There are 11,000 ha of naturally salty soils located in the driest region (Ovce Pole). Salinization and alkalization have been thoroughly studied. These processes are rarely of anthropogenic origin. It is notorious fact that irrigation activities especially in dry areas lead to salinization, but due to absence of monitoring or any research, it’s intensity, dimension, and state cannot be exactly defined.

## VI.3 Policy

Soil protection in the Republic of Macedonia is regulated by several laws, including those covering the matters of nature protection, the Law on Environment, the Law on Agricultural Land, etc. According to Article 2 of the Law on Environment (Official Gazette of the Republic of Macedonia No. 53/05 and amendments Official Gazette of the Republic of Macedonia No. 81/05), the scope of the law includes protection and improvement of the quality and the state of environmental media, including the soil. The same Law, in its Article 9, stipulates the implementation of the polluter pays principle, and Article 13 provides for the precautionary principle, that would help to avoid local contamination of soil in future. Article 36 stipulates internal monitoring for legal and natural persons possessing sources of emissions and by their activities make impacts on one or more media and areas of the environment.

The Law on Nature Protection (Official Gazette of the Republic of Macedonia No. 67/04), Article 11, restricts the change in land use, and Article 12 prohibits nature use in a manner that leads to soil degradation and loss of its fertility. The Law on Agricultural Land (Official Gazette of the Republic of Macedonia No. 25/98), in its Article 31, provides for the protection of agricultural land against pollution and infection, for the purposes of safe food production, human health protection, protection of flora and fauna and uninterrupted use and protection of the environment. The same Article stipulates that the Ministry of Agriculture, Forestry and Water Economy specifies matters that are harmful to agricultural land, determines their maximum permissible concentration in soil and measures to be undertaken on agricultural land of higher concentration of harmful matters in order to reduce them below the permissible levels. However, this has not been achieved yet. Article 32 of the same law specifies the measures and the activities undertaken for the purposes of protection against and prevention of erosion of agricultural land, presence of contaminating matters and potential adverse effects on human health or on the environment.

The Law on Spatial and Urban Planning of 1996 determines several types of spatial plans: General urban plan (setting the overall organization of cities, including zoning and land use aspects), Detailed urban plan (spatial arrangement of land plots up to 30 ha, containing details of land use) and Urban documentation (plan for rural settlements). There is no legislation that completely treats this problematic. There is no institution (scientific; expert; political) that would treat this problematic completely, because different institutions deal with it. Most of these institutions make their surveys with other purpose, but the findings can be used to get data on the soil degradation. The enforcement of the laws is in the hands of different authorities, such as the State Inspectorate of Environment, and Inspectorate of Agriculture. The lack of clear definition of institutional competences and absence of control and penalties make the relevant regulations ineffective.

The Ministry of Environment and Physical Planning (MEPP) has initiated activities aimed at identification of the status of the soils, in line with the requirements of the European Environmental Agency and the first national report under the Soil Topic Center was submitted in 2004. The complexity of this issue is even greater considering the fact that the EU relevant legislation is under establishment. After the adoption of the future Framework Soils Directive by the EU, the Republic of Macedonia should undertake its transposition in the Macedonian legislation. Objectives of the MEPP are:

- Development of comprehensive policy of soil protection;
- Establishment of regular soil monitoring;
- Prevention and reduction of soil and forest areas degradation;
- Prevention of chemical and physical degradation of soils under agricultural crops and reduction thereof;
- Ensuring steadiness of forest ecosystems through natural restoration and maintenance of their stability and biological diversity.

## VI.4 Environmental management and access to information

Permanent monitoring, i.e. systematized measurement, monitoring and control of the state, quality and changes in the soil as environmental media in the Republic of Macedonia does not exist. The only monitoring of the state of the soil concerning certain heavy metals, such as lead, zinc, and cadmium was carried out in the area of Veles in the course of 2004 and 2005, as one of the most endangered and most contaminated areas in the country, due to the long operation of the Lead and Zinc Smeltery. Such monitoring was conducted by the Institute for Health Protection in Veles.

There has been no comprehensive strategy and national policy for contaminated sites management or specific legislation to regulate contaminated sites investigation and cleaning up. In order to overcome environmental impacts on areas with identified environmental degradation and to minimize potential threats to environment, the strategy should include: polluters identification, preliminary investigation of potentially contaminated sites, comprehensive examinations to determine accurate contamination and contaminated area, to be followed by remediation plan, including specific investigations in remediation and undertaking of measures to reduce negative impacts on human health or environment. We anticipate the following processes and projects in the coming years:

- Making and digitalisation of soil map in the scale 1:50,000;

- Introduction of Soil Information System – Forming a body that would completely cover this complex problematic i.e. would collect the data; would work on adopting appropriate legislation; would organize monitoring and many other organizational works related to this problematic;
- Establishing of soil monitoring system;
- Fetching Law regulative for maximum permissible limits of harmful substances in soils;
- Making a map for locations where soil degradation is manifested;
- Defining of resources which cause soil pollution;
- Fetching Law regulative against soil erosion;
- Fetching Law regulative for soil fertility control;
- Preventing activities of negative soil degradation by implementing measures for positive anthropogenisation of soils;

## VI.5 Outlook

There has been an increasingly recognized need to adopt appropriate law in the Republic of Macedonia, to regulate soil from several points of view, as environmental medium. It is necessary to establish the maximum permissible concentrations in soils for different purposes, with regard to heavy metals, certain substances as pesticides, polycyclic aromatic hydrocarbons, halogen hydrocarbons, etc. According to the current legislation, as well as to the forthcoming new legislation, there is an evident need for establishment of permanent monitoring of the soil, with an accent on areas with highest contamination of the soil.

The presence of industrial and commercial sites with certain degrees of soil degradation in Macedonia, as well as tailings disposal sites as part of the operations of the mines in the past, pose the necessity to undertake measures and activities for remediation and reclamation of the soil, i.e. restoration of soil and environment as a whole into their original state, a state that would not pose risks for biodiversity and for human health.

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# VII. Overview of soil information and soil protection polices in Greece

Sid. P. Theocharopoulos

N.AG.RE.F. Soil Science Institute of Athens
S. Venizelou 1 Str., 14123 Lykovrissi, Athens, Greece
Tel.: + 30 210 2819059; +30 210 2817302; Fax: + 30 210 2842129
Sid_Theo@nagref.gr; Sid_Theo@internet.gr; ssia@otenet.gr

**Summary**

*In this chapter the soil mapping situation, soil data availability, soil information systems, soil monitoring and soil protection polices in Greece are presented and some recommendations are made regarding these not only for Greece but for the whole of Europe. Detailed soil mapping of agricultural land has not yet been completed. Soil data bases have been developed in almost all the soil science institutes of National Agricultural Research Organisation (N.AG.RE.F.), and in the soil science dept, of the Agricultural Universities of Athens and Thessaloniki. Soil information systems are used to produce soil mono and polythematic maps, including land capability, land suitability, optimal crop fertilization, land degradation, environmental assessment, and land reclamation maps. Soil protection polices in Greece are focused on the identified threats of erosion, organic matter decline, salinization, sodification, compaction, sealing, contamination, decline of biodiversity, acidification, floods and landslides, as well as on change of land use. The National Committee to combat desertification has prepared a plan, the nitrates action plan is under progress in areas sensitive to nitrate leaching, while the Ministry of Rural Development and Food has developed and strongly supports the Code of Good Agriculture Practices. The need and the growing demand for soil data and soil protection enhances the need for soil data to be digitized, stored in user friendly GIS linked to national and international bases. National monitoring systems should be established in each EU country based on new technologies, a minimum set of parameters/indicators, quality control/assurance procedures, and accompanied by traceability rules.*

## VII.1 1 Introduction

In this chapter, the situation in soil information and protection in Greece, will be presented following Aggelides and Theocharopoulos (1992) and Yassoglou, (1996, 1999, 2005). This includes soil mapping, soil data bases and information systems, soil and land evaluation procedures, soil monitoring and soil protection polices. The aim is to strengthen the collaboration between EU member countries and South-eastern European countries in soil related issues by studying the current situation as regard to describing, classifying, mapping, evaluating, and monitoring soils and the relative legislation and action plans to protect soil and through it soil processes affecting soil and water quality. This will assist in planning the next harmonization steps throughout Europe and in supporting the soil protection directive, which is under development and implementation.

### *VII.1.1 Soil mapping and data availability*

Before any plans can be drawn up relating to the use, management or even protection of the soil, survey and mapping are necessary to study, describe, classify, evaluate and store soil data in a soil database system, followed by data processing through a Geographical Information System (GIS). According to the last census (2001), the total area of Greece is 13,195,740 ha, 3,943,590 ha (29.9%) of which is the agricultural land. Soil surveys of agricultural land, initiated in the 1930s, has been carried out in the past by several institutes of the National Agricultural Research Organisation (N.AG.RE.F.), namely: The Soil Science Institutes of Athens and Thessaloniki, the Soil Mapping and Classification Institute of Larissa, and the Forestry Institute of Athens, and by the Land Reclamation Service of the Ministry of Agriculture, the Greek Agricultural Universities of Athens and Thessaloniki, the Nuclear Research Centre “Democritos” and the Institute of Chemistry and Agriculture “N. Kanelopoulos” of the fertilizer industry, Pireas (Aggelides and Theocharopoulos, 1991, Yassoglou, 1996, 1999, 2005).

The soil mapping scale in Greece, varies from 1:5,000 to 1:50,000 for detailed mapping, from 1:50,000 to 1:100,000, for semi-detailed scale, and from 1:100,000 up to 1:250,000 for reconnaissance scale mapping. The soil mapping program of agricultural land has never been a continuous program resulting the complete mapping of agricultural land. Therefore, the only available soil map for the whole of Greece is the 1:500,000 soil association map combiled by Yassoglou (2005), Fig. VII.1, and the 1:1,000,000 and 1:5,000,000 soil maps of Europe compiled by the European Soil Bureau Network (ESBN). The EU has contributed to the soil map project through the second protocol agreement Gr/80-3/C1/12.5.80, “contribution to the soil map project of Greece”, offering to Greece the amount of 3,750,000 ECU, which was allocated and used for scientific instruments, postgraduate training courses for soil surveyors, a soil mapping pilot project in Western Greece, and for air-photography of the total area of Greece, on a scale of 1:20,000.

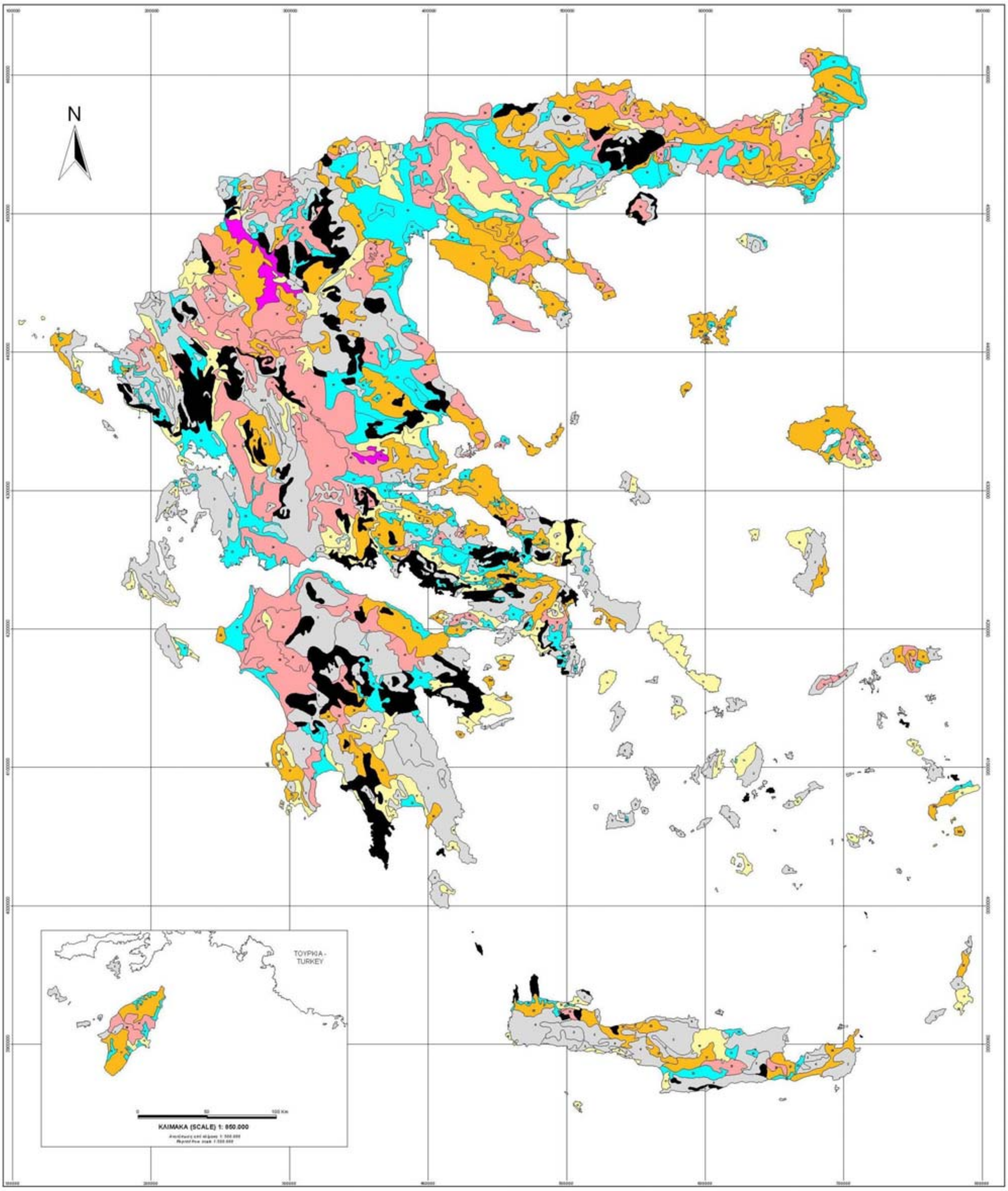


**Fig. VII.1. Soil Association map of Greece at scale of 1:500,000 (Courtesy of N. Yassoglou).**

The soil classification and mapping systems varied, and included the Russian system (Glinka, 1927), the 1938 USA system (Thorp and Baldwin, 1938), the French system (Aubert and Duchaufour, 1956), and more recently Soil Taxonomy (Soil Survey Staff, 1975, and subsequent modifications) and the FAO system (FAO/UNESCO, 1990) were used.

### *VII.1.2 Soil Mapping of agricultural Land*

According to recent data, the agricultural area mapped throughout Greece by all the N.AG.RE.F. Institutes accounts for about 2,0 million ha, while 780,000 ha of Agricultural Land (Yassoglou, 2005) have been mapped at detailed scale. From all these data about 350,000 are in electronic form, which are mainly in ARC/INFO format. The Land Reclamation Service of the Ministry of Agriculture has in analogue form, the maps and the soil survey reports on different scales of about 2,764,556 ha, most of which are in the lower alluvial plain and mainly for drainage or irrigation purposes.

The taxonomic unit of each mapping unit in the detailed soil survey, is defined to the level of Subgroup or Great Soil Group according to Soil Taxonomy (Soil Survey Staff, 1975 and subsequent modifications) and then further subdivided, according to a number of soil parameters, to soil series and soil phases. The parameters and characteristics defined and included are: drainage, texture of each soil horizon or of soil depth increments (0-25 cm, 25-75 cm, 75-150 cm), presence of gravels and stones, slope, evidence of erosion, abundance and distribution of carbonates, and specific limitations (like calcic or petrocalcic horizon) which, if present, strongly affect soil performance (Tziolas, 1985, Yassoglou, 1999).

In the mapping unit symbol of the Progressive Detailed Soil Survey system followed, all the above parameters are included in coded form accompanied by the taxonomic symbol as follows:

$$A\frac{234*}{B13_{Ca1F}}Ioxt \tag{1}$$

where:

A – describes drainage (in this case no hydromorphic features, within a depth of 150 cm)
2 – describes texture of soil between 25-75 cm depth (in this case Loam)
3 – describes texture of soil between 75-150 cm depth (in this case Clay)
4 – describes texture of soil between 0-25 cm depth (in this case Clayloam)
B – describes slope class (in this case 2-6%)
1 – describes erosion (the topsoil has been removed in less than 30% of the area of the mapping unit)
3 – describes presence of $CaCO_3$ (in this case high content of $CaCO_3$ throughout the profile)
Ca1 – describes in this case the presence of calcic horizon at soil depths of 60-100 cm
F – describes in this case salinization
* – in this case presence of gravels, without (*) means no gravels and stones
Ioxt – describes the soil classification:
- I – describes the order (Inceptisols)
- o – describes the suborder (Ochrepts)
- x – describes the great group (Xerochrepts)
- t – describes the subgroup (Typic Xerochrept)

The rate of detailed mapping has slowed, in recent years because of lack of an ongoing strategy for national mapping. At present soils are mapped on request by local authorities to meet the needs for optimal fertilization, planning irrigation, agricultural management, environmental management, and land planning. In this context, the mapping project of an area of about 500,000 ha in Eastern Macedonia and Thraki has been announced to be completed during the next two years, while in the Kozani area a detailed mapping project of an area of 36,000 ha is in progress by N.AG.RE.F., Soil Science Institute of Thessaloniki.

### *VII.1.3 Land mapping of the Forestry area*

Mapping on the scale 1:50,000 of Forest and Range Land has been completed for the whole of Greece. This land mapping, conducted by the Greek Forestry Service and the Athens Forestry Institute (N.AG.RE.F.), was based on the site parameters: geology, physiography, vegetation, degree of human interference, soil depth, soil erosion, aspect and slope. The mapping units were defined parametrically and drawn onto 1:50,000 maps using parametric overlaying (Nakos, 1983). Land mapping is not strictly soil mapping, but is a useful reference for the construction of soil maps in the hilly and mountainous areas of the country.

More than 2,000 profiles have been described, sampled, analysed and classified according to the Soil Taxonomy and FAO systems. The symbol used to describe the mapping unit is in the form (Nakos, 1983):

$$X5X3\text{-}124\text{-}8\text{-}D6NE \qquad (2)$$

where:

X – describes the superficial geology (in this case schist)
5 and 3 – describes the physiography (in this case middle slope, rounded summits)
1 – describes soil depth (in this case deep)
2 – describes erosion (in this case no erosion, moderate erosion)
4 – describes slope (in this case moderate and gentle)
8 – describes the serial number of the units
D6 – describes the land region (in this case deciduous zone)
NE – describes aspect (in this case north-east)

## VII.2 Soil Information Systems (SIS)

### *VII.2.1 Data bases (DB)*

Many soil information systems (SIS), which combine Geographical Information System (GIS) and Data Base (DB), have been designed and implemented, e.g. Kollias and Malliris (1990), Theocharopoulos et al., (1990, 1994a, 1995), Davidson et al., (1994). Information for about 350,000 ha of soils is in digital form, while soil databases exist in a number of institutions, where topological and semantic data are stored.

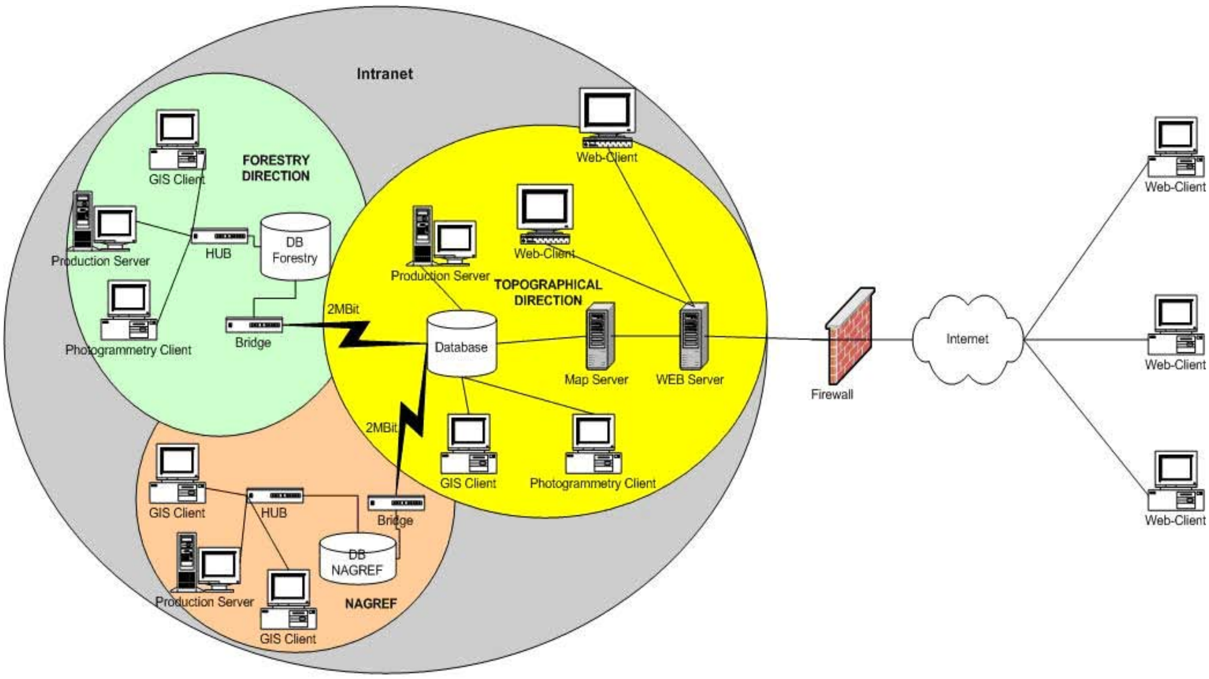


**Fig. VII.2. SIS system for the dissemination of Agricultural Spatial Data (Courtesy: Dr B. Tsigas and A. Panayiotopoulos).**

Soil survey report data, soil mapping unit data, sampling point data, profile data including horizon designation and depth, soil horizon (or sampling depth increment) physical and chemical data like textural class (sand, silt, clay), cation exchange capacity, exchangeable cations, organic matter, pH, carbonates, total N, P and K, electrical conductivity, bulk density, soluble salts, sodium saturation, macro and micronutrients and heavy metal content are determined and stored in the SIS. Soil water infiltration, and soil permeability, as well as bulk density, are occasionally recorded. Digital mapping and geostatistical techniques were developed to predict the distribution and mapping of soil parameters and heavy metals content by many researchers like

Theocharopoulos et al., (1997) and Gatsios et al. (2004). Data are stored either in attached to GIS, or to an Oracle, data base system or in another data base. Soil mono and/or polythematic maps are printed, while the data bases are used to produce Land Capability Maps or Land Suitability Maps as well as other maps.

As described by Yassoglou (2005), all the Institutes and Universities involved with soil surveys are developing their own Soil or Land Information System mainly in ARC/INFO software. Also AGROLAND S.A., which is a non profit private company founded in 1998 with sole shareholder the Ministry of Rural Development and Food (MRDF), has its own Land Information System.

### *VII.2.2 Soil data dissemination*

The usefulness of soil database and information systems has not been recognized in the past to the degree that it deserves. This has changed recently, and there are many signs of a much better appreciation of soil data and more demands by researchers, private enterprises, local authorities and communities. The weak points of soil data dissemination are that soil data either do not exist or that they exist in neither digital form nor stored in databases. Soil survey reports and traditional soil maps are usually kept in analogue form. The first step to overcome those problems is to digitize all soil maps and soil survey reports, and to store all existing soil data in properly designed soil information systems. The next step is for all the Greek soil databases to be interlinked so that soil data can be easily available to the public. Through a project in the 3rd Operational Programme, funded by the EU under the action: “Geographical Information System for the Management of digital geographical information of the agricultural sector”, all soil maps which are not in electronic form will be digitized and made available through a portal. This portal is specially designed by the consultant, the project manager and the project team through the web network to the potential users (Fig. VII.2). Forest land and cover maps on the scale of 1:50,000 will also be incorporated in this portal.

## VII.3 Use of Data Bases and Geographical Information Systems (GIS)

Using soil and land data in GIS systems, different thematic soil maps, land evaluation maps for crop suitability, land degradation, environmental assessment and land reclamation have been produced as presented below.

### *VII.3.1 Land capability, land suitability, crop selection and crop fertilization*

Soil data stored in a GIS database system are used to be combined with physiography, weather and plant or tree requirements to produce land capability maps according to Klingebiel and Montgomery (1961), or land suitability maps (FAO, 1976; Sys, 1985). The main procedures followed are qualitative, Theocharopoulos et al. (1995).

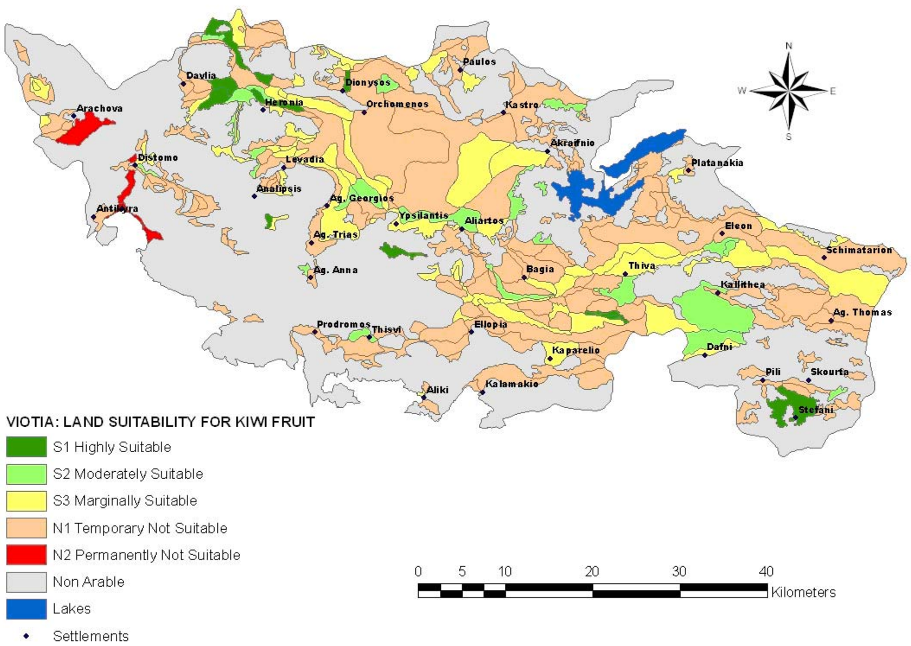


**Fig. VII.3. Land suitability for kiwi fruit of Viotia prefecture.**

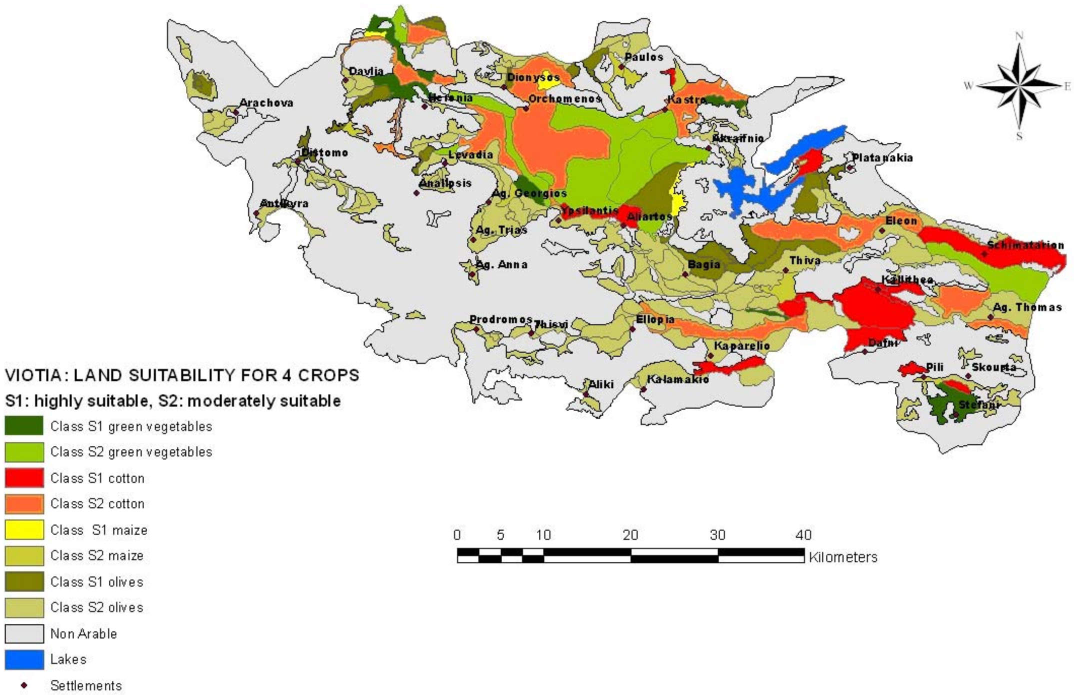


**Fig. VII.4.Optimal land use plan for green vegetables, cotton, maize, and olives in Viotia prefecture.**

However, some attempts are quantitative (Danalatos, 1993), while Davidson et al., (1994) studied the use of Boolean and Fuzzy set methodologies for land evaluation in Greece. Theocharopoulos (1992), based on a 1:100,000 scale soil map and in cooperation with Prof. D.A. Davidson (University of Stirling, UK), prepared a land suitability map of the soils of Viotia perfecture (150,000 ha) for wheat, winter cereals, olive trees, kiwi fruit (Fig. VII.3), maize, green vegetables and cotton. Davidson et al., (1994) prepared an optimal land use plan for green vegetables, cotton, maize and olives (Fig. VII.4).

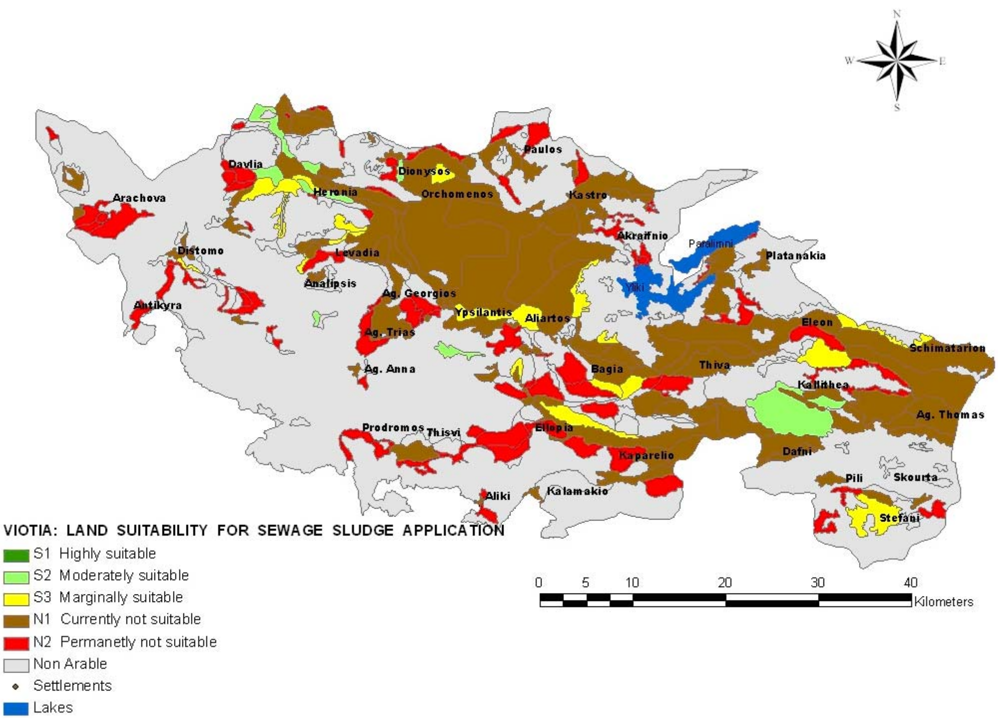


**Fig. VII.5. Land suitability for sewage sludge application to soils of Viotia prefecture.**

Assuming green vegetables offered higher income than cotton, cotton than maize and maize than olive trees. This was achieved through the following steps: (1) highly suitable (S1) land for green vegetables was allocated to this use, (2) remaining high suitable (S1) land for cotton was allocated to this use, (3) remaining highly suitable (S1) for maize was allocated to this use, (4) remaining highly suitable (S1) land for olives was allocated to this use, (5) the same procedure was followed for moderately suitable (S2) land etc. Theocharopoulos et al., (1998) developed a GIS expert system to apply sewage sludge to soils in an approach friendly to the environment (Fig. VII.5).

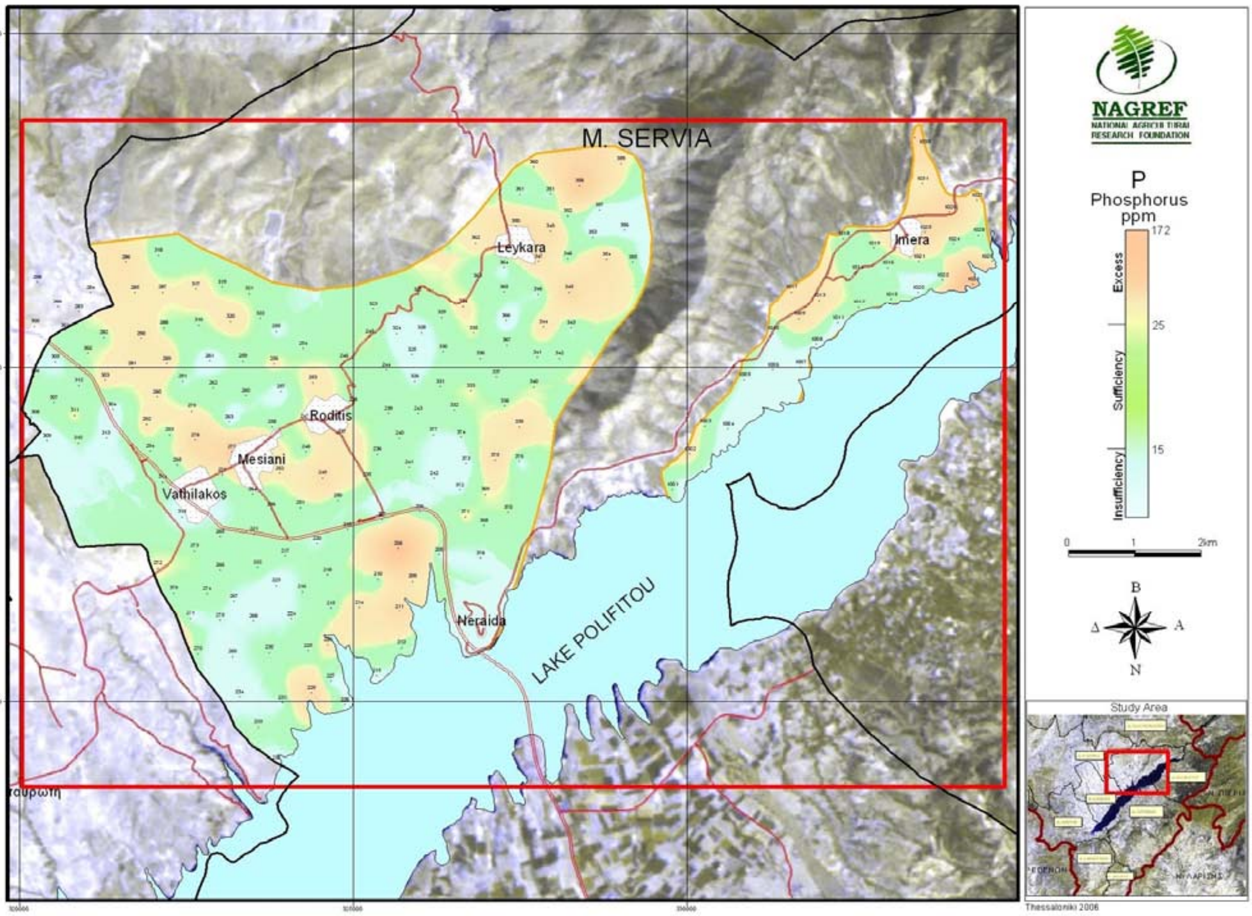


**Fig. VII.6. Prediction P-Olsen in soils in District of Serbion.**

Belemis et al., (2003) described the methodology, using GIS databases and new technologies, to recommend fertilization programmes fulfilling the Code of Good Agricultural Practices. The Soil Science Institute of Thessaloniki is implementing a project for 36,000 ha where fertilization and irrigation needs will be proposed at the farm level. Using soil data bases and geostatistical techniques, nutrient prediction is taking place at any point in the field, as shown in Fig. VII.6. Using the 1:1,000,000 data base, Yassoglou (1990) has prepared a map of low, medium and highly suitable mapping units for urea fertilization.

### *VII.3.2 Land degradation, environmental assessment and land reclamation*

Soil data bases and GIS systems have also been used to access land reclamation, land quality, land degradation and environmental assessment as described in more detail by Yassoglou (1999, 2005). In the framework of the National Action Plan to Combat Desertification, Yassoglou (1999), prepared a 1:1,000,000 potential desertification map based on an interpretation of the ESBN soil database. Soil texture, depth, drainage, slope, vegetation index and climate quality were used to determine land falling into one of the four risk clsses, i.e. none, low, medium or high erosion risk classes (CORINE, 1992; Yassoglou, 2005). Kosmas et al. (2005) used detailed soil survey data (parent material, texture, depth, drainage, rock fragments, and slope) to define the "Environmentally Sensitive Areas (ESA's)", with emphasis on soil erosion and desertification.

As also described by Yassoglou (2005) a scientific team from the National Agricultural Research Foundation, the Agricultural University of Athens, and the National Committee to Combat Desertification, has developed in GIS an empirical system for various crops for nitrogen fertilisation in order to reduce the nitrate leaching risk. Theocharopoulos (1998) combined GIS technology and results from an erosion model, built in Model Maker software, to print an erosion rates predictions map of the Viotia prefecture (Fig. VII.7).

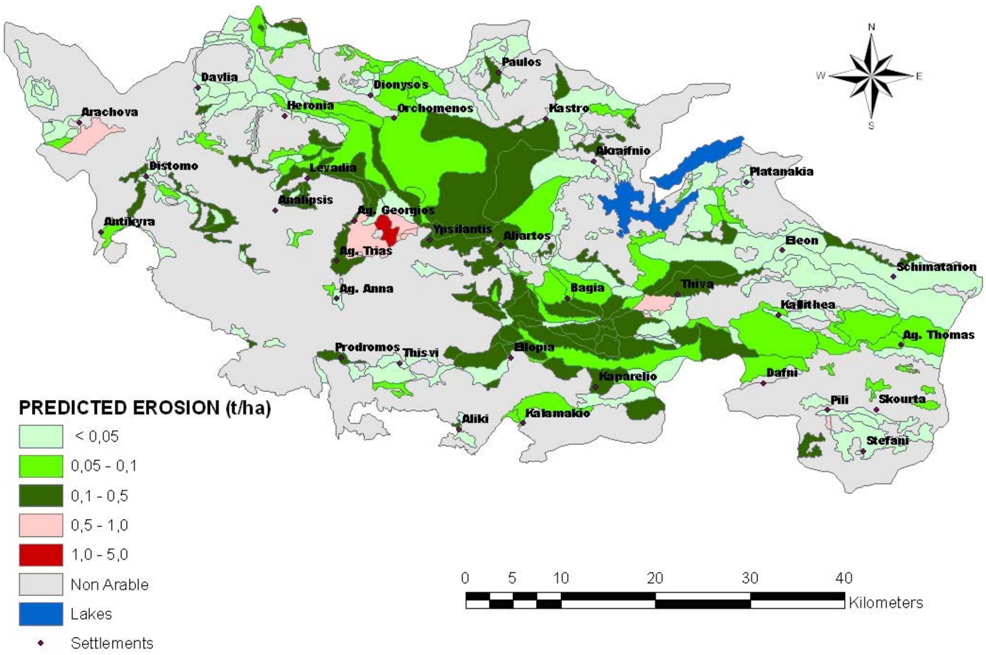


**Fig. VII.7. Prediction of erosion rates in the soil mapping units of Viotia prefecture**

Most of the soil surveys of the Land Reclamation Service of the Ministry of Agriculture have been used for land reclamation purposes and, more specifically, for drainage or irrigation projects. In this context the soil survey reports are accompanied by irrigation and water permeability classes maps based on the US Bureau of Reclamation (1953) system. Soil morphology, topography and hydromorphy, slope, depth, texture, and water permeability throughout the profile have been used to design drainage or irrigation system in the bottomlands of the alluvial plains. Saline and sodic soil reclamation plans have been designed through the leaching fraction requirement. Based on the soil survey data, the Land Reclamation Service of the Ministry of Agriculture and the Soil Institutes of N.AG.RE.F. have prepared a number of environmental impact reports for development projects. Forest sites were classified into suitability classes for better forest management, reforestation, etc (Nakos, 1984), by using parent material, physiography, aspect, soil typological unit, soil depth, slope and surface stoniness.

## VII.4 Soil protection polices in Greece

### *VII.4.1 Soil threats reported*

The following major groups of degradation processes affecting both soils and soil water can be distinguished in Greek soils (Theocharopoulos and Aggelides, 1991, Yassoglou, 1987, Theocharopoulos and Panoras, 2000):

- Accelarated soil erosion
- Organic matter decline
- Soil salinization and sodification
- Soil compaction
- Soil sealing
- Soil contamination (by heavy metals, and other chemical)
- Decline of biodiversity
- Acidification
- Floods and landslides
- Land use change (exclusion of soils from its natural functions, urbanization)

**Soil erosion** is not a recent phenomenon especially in the Mediterranean region. Forests and bush fires, plant cover removal or overgrazing, climatic change, soil structure deterioration, rainfall pattern and intensity, top soil treatments, current land use and cover crop residues removal or burning are the main factors accelerating erosion (Davidson and Theocharopoulos, 1992; Theocharopoulos et al., 2003). Danalatos et al. (1998) found that current land use also affects erosion. All the above affects flood and landslide frequency. Non proper treatments, i.e. monoculture combined with the burning of residues decrease soil organic matter, with all the consequences to soil structure, erosion, fertility etc.

**Salinisation and sodification** in the downslope soils near the sea, where water is stagnant, or through the use of low quality irrigation water is a serious problem in the plains of Greece (Misopolinos, 2000; Koukoulakis et al., 2000). The use of more powerful heavy machinery has led to compaction (Kostopoulou, 2000) and loss of structure, and has indirectly accelerated soil erosion (Terzoudi and Gemtos, 2000). The ensuing intensification of agriculture has led to increased and sometimes excessive application and leaching of fertilizers (Theocharopoulos et al., 1993, 1994b), manure, sewage sludge and pesticides (Papado-poulou-Mourkidou, 1998; Lolas, 1998), with consequent soil contamination and decline of biodiversity. Haidouti et al., (1985) reports the presence of mercury in some Greek soils.

Industrial evolution in Greece seems to have brought about, directly or indirectly the additions of wastes and pollutants, including heavy metals and acid rain to the soils. Mimides et al., (2000) reports **pollution** of subsurface and hydrological formations from petroleum. The need for housing, industry, infrastructure etc around big cities and near the sea has given rise to the removal of best quality land from its natural function through its allocation to other uses.

Since soil is in close contact in nature and interact with water resources, pollutants reach deeper soil levels and ground water through diffusion, or mass flow or preferential bypass flow either in solution or suspension. In addition, soil processes such as soil erosion, leaching, macropore flow and mineralization of humus affect water quality. In this context and based on existing soil data, Kallergis (1977) defined the areas of Greece vulnerable to nitrate leaching from agricultural activities, while Karyotis et al. (2002) describe the grouping of soils of Thessaly into different soil classes (I-VIII) with recommended total nitrogen fertilisation and total water application.

### *VII.4.2 Soil protection actions*

Soil resources as well ecosystems in Greece, as explained above, have been subjected to irreversible damage for many years. Therefore actions needs to be taken against physical deterioration, which is related to soil physical properties, against pollution and contamination through air, water, terrestrial pathways and against biological degradation and loss of biological activity as a result of decreases in populations and biodiversity.

The national strategy for soil and water resources considering land use change and climate change was presented, described and discussed in a Conference-Workshop organized by the Ministry of Rural Development and Food (MRDF) in Athens, 25$^{th}$ February 2000. Possible activities in scientific research within the national or European legal framework to preserve improve and rehabilitate all soil functions and properties for a sustainable development are presented by Misopolinos *et al.* (2000), as follows:

- Improvement and broadening of scientific and technical knowledge of soil functions.
- Scientific knowledge dissemination.
- Selection of best soil uses in relation to soil functions.
- Development of the proper tools to monitor, protect and improve soil quality.
- Development of soil quality monitoring of Greek soil resources for a sustainable management.
- Improvement of the deteriorated soil functions.
- Mapping and evaluating of soil resources.
- Monitoring and management of soil resources.
- Research for the soil resources.
- Legislation.
- Infrastructure for all the above.

The National Committee to combat desertification has prepared the National Action Plan (Yassoglou, 1999). The Ministry of Agricultural Development and Food is implementing the "*Greek Action Plan*" for the mitigation of nitrates in water resources of vulnerable districts such as Thessaly and Kopais (Kallergis, 1997). The Greek Action Plan, is in compliance with the nitrate directive 91/676/EEC and correlated to the Code of Good Agricultural Practice. It comprises a set of measures and practices targeting the protection of surface and groundwater aquifers from nitrate pollution of agricultural origin, through rational management of inorganic fertilisers by combining it with irrigation schemes to safeguard income and protect the environment. In this context the maximum admissible levels, type and timing of nitrogen fertilisation for individual main crops in different soil class and hydrological structures are determined in advance.

The Land Planning and Protection of the Environment Directive of the Ministry of Rural Development and Food has produced the Code of Good Agricultural Practice (CGAP) and through the agro-environmental program, the environment is directly and soil indirectly protected. This in the Framework of Reg (EU) 1257/99 which incorporates protection of the environment into rural development. Subsidies are offered to farmers who comply with practices friendly to the environment such as reduced nitrogen inputs and anti-erosion measures. Soil is also protected through water protection measures such as protection of different lake ecosystems throughout Greece, and through other initiatives of the Ministry of Agricultural Development and Food such as programs for the extensification of animal husbandry, organic farming or organic husbandry, long time set aside land, protection of sloping landscapes etc. Also, through the integrated crop management system, productive soils are protected from agrochemical residues. In addition, compaction and biodiversity are protected through the Code of Good Agricultural Practices. The use of sewage sludge is in accordance with EU Council Directive 86/278. Urbanisation, housing, industry, infrastructure and recreation cause irreversible soil use changes and legal protection of fertile land is therefore necessary.

### *VII.4.3 Soil monitoring*

Damage to the soil by degradation depends firstly on the type of degradation process involved and secondly on the soil “resilience” (Greenland and Sztabolcs, 1994), while the first step towards soil protection is monitoring. Soil monitoring is quite difficult due to soil complexity, spatial and temporal variability, and scaling. Also the specific threats for each soil type have to be defined since some threats require systematic monitoring, while others may need more focused monitoring. Stratification of Greek soils according to susceptibility to each type of threats would allow the development of targeted monitoring approaches for each of these.

The establishment of soil quality indicators and soil monitoring in Greece has lagged behind. The only monitoring program in Greece, is through application of the “Greek Action Plan for the mitigation of nitrates in water resources” (Directive 91/676/EEC (European Commission, 1991) in the areas of Thessaly, Kopais (Viotia) and Hlia (W. Peloponisos), under which farmers are paid subsidies to reduce fertilizers application and soil and water samples consequently contain low levels of nitrates. The Ministerial decision 138/30.9.2005 determines the measures and monitoring scheme. Also, monitoring is taking place through a project for the protection of European Forests from air pollution which is implemented by N.AG.RE.F., Institute of Mediterranean Forest Ecosystems & Technology of Forest Products (IMFE & TFP). Soil sampling takes place according to European Regulations 3528/86 (annual monitoring of the forest due to air pollution) and Regulations 1091/94, 690/95, 1390/97. In the framework of the project: “Effect of air pollution to the forest ecosystems”, in the Level I sub-project in fifteen forest experimental sites, sampling takes place, and in the Level II sub-project in four intensively monitored sites. Soil properties monitored are pH, CEC, organic matter content, total N, total P, and total basic cations. In the four intensively monitored sites, soil solution is collected to be analysed (Michopoulos, pers communication).

Monitoring needs to be of low cost, remote sensing, technologically improved, GIS or other technology based and to start from point sources (industrial sites, land fills, military sites, etc). A minimum set of common soil parameters or quality indicators for monitoring could be selected. Also it needs to be organized under standard quality control/quality assurance procedures, including ring test, benchmark sites, education in soil classification and mapping. Harmonized and standardized soil sampling and sample preparation, which is a serious error or uncertainty introducing factor (Wagner et al., 2001) throughout Europe (Theocharopoulos et al., 2001) should be adopted. Accredited laboratories both for soil sampling and soil analyses, with established coordination throughout Europe, for monitored parameters and traceability (Theocharopoulos et al., 2004), should be involved in the soil monitoring project. Each country should develop its own monitoring system which needs to be part of a European monitoring system.

## VII.5 Conclusions and recommendations

Global sustainable development is today universally sought. Also the EU, through its new Common Agricultural Policy (CAP) incorporating environmental issues in rural development and following commitments to the World Trade Organization (WTO) and the United Nations Environmental Program, seeks to achieve:

- Safe, healthy, competitive and top quality food
- Sustainable rural development
- Protection of the environment, including from the climatic change
- Knowledge base and system, economy in the service of: policy, industry, civil society, and scientific community.

All the above enhances the need for soil data, soil maps and soil data bases, with a resulting growth in the demand for soil data, soil monitoring and soil protection in different regions and on different scales. It has become obvious, that in order to ensure the protection of the environment in different geographical areas and in any land use change soil maps and soil data bases must be used. This explains the growth in demand in Greece also for soil data, soil monitoring, and soil protection, which has to be satisfied. In this context:

1. Soil data should be digitized and stored in global, user friendly GIS, linked to national and international bases. This implies that mapping (traditional or digital) of agricultural land should be completed (if not on detailed at least on semidetailed scale), and pilot research projects should be implemented using new technologies in collecting, classifying soil data, and developing pedotransfer functions to manage, interpret and use soil data.
2. Soil protection actions following the REG (EU) 1257/99 which incorporates environment in rural development, and practices friendly to the environment should be intensified.
3. A national, harmonized (at EU scale) soil monitoring system must be established in each EU member state based on new technologies, with a minimum set of parameters/indicator and combined with quality control/assurance procedures of soil sampling, treatment and analysis, and following traceability rules.


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# VIII. Overview of soil information and soil protection policies in Hungary

Tibor Tóth[1], László Pásztor[1], György Várallyay[1], Gergely Tóth[2]

1 Institute for Soil Science and Agricultural Chemistry
of the Hungarian Academy of Sciences
Herman O út 15. Budapest 1022 Hungary
Tel.: + 36 1 2243616; Fax: + 36 1 3564682
tibor@rissac.hu; pasztor@rissac.hu; g.varallyay@rissac.hu

2 Land Management and Natural Hazards Unit
European Commission, Directorate General JRC, Institute for Environment
and Sustainability, TP 280, Via E. Fermi 1, I-21020 Ispra (VA), Italy
Tel.: + 39 0332 785535; Fax: + 39 0332 786394
gergely.toth@jrc.it

**Summary**

*Although Hungary has a unique history of soil research, the existing, easily available, on-line databases are not substantially utilised so far. Small scale maps of most types of soil degradations are easily available based on the 1:100,000 scale "AGROTOPO" soil database. There is a complete series of 1:25,000 scale "Kreybig" practical soil maps which are partly digitized and made available in the Kreybig Digital Soil Information System. The most detailed soil surveys at 1:10,000 scale genetic soil mapping were performed for ca. 70% of the agricultural area. Nevertheless, there are very promising applications based on these databases and the availability of a working digital cadastral registry system provides good basis for new approaches. One such application is the D-e-Meter on-line soil valuation system, which is based on the real-time calculation of D-e-Meter soil fertility index in the GIS of 1:10,000 scale genetic soil maps. Besides maps, there are independent soil databases for soil profiles and also exclusively for the plough layer of agricultural fields. There is a working monitoring system, consisting of 1236 points all over Hungary sampled since 1992. Soil protection is institutionally realized by a series of laws and administrative units. A National Soil Protection Strategy has been formulated in order to prevent soil degradation.*

## VIII.1 Introduction

As a result of former soil surveys, a large amount of soil information has been accumulated for Hungary. The collected data are available in different scales: national, regional, micro-regional, farm and field level and generally, they are related to maps (Várallyay, 2005). This contribution attempts to complement the report of Várallyay (2005) with new information. There is an outstanding record of collecting soil information in Hungary. The historical past is summarized in several publications (Ballenegger and Finály, 1963). As in other countries in the early period of soil mapping, until the First World War there were two tendencies: special mapping of selected, usually small areas and preparation of very small-scale maps, based on scarce observations and continental-scale conceptual models. In Hungary, the first soil (that time called agrogeologic) map was compiled in 1861 (Szabó, 1861) for the area of two counties at the scale of 1:576 000. A major achievement was the first complete soil map of Hungary prepared by Imre Timkó in 1914 (Fig. VIII.1). During the pre-war and after-war periods of 1935-1951, the "Kreybig" practical soil mapping was completed and displayed on maps at 1:25,000 scale. From the 1960's, the 1:10,000 scale mapping of the agricultural land was performed. From 1989 no systematic large-scale soil mapping has been carried out.

In the 1990's, much of the small-scale soil related data were converted into digital format and organized into spatial soil information systems (SSIS), including the AGROTOPO (Várallyay & Molnár, 1989), HunSOTER (Várallyay et al., 1994), MERA (Pásztor et al., 1998) and SOVEUR (Várallyay et al., 2000). Nevertheless more detailed SSIS are anticipated by numerous potential users (land users, planners, policy makers, legislative officers, engineers, scientists etc.) and fields of interests (environmental protection, land evaluation, precision farming etc.). The next step in spatial resolution would be featured by a scale of 1:200,000 up to 1:20,000 (with a nominal spatial resolution of 40-400 m or 0.16-16 ha in territorial units) (Lagacherie & McBratney, 2004), also required by European Soil Protection Strategy (CEC, 2002) and in accordance with the principles of INSPIRE (CEC, 2004; Dusart 2004).

Digitisation and GIS adaptation of the results (1:25,000 scale maps and complementary explanatory booklets) of the practical soil-mapping programme hallmarked by L. Kreybig[6] is under construction (Szabó et al., 2000). The TirSOTER project generated a digital soil database for the territory of Pest County, integrating soil profile data (3195 profiles) and information content of 104 sheets of hand-drawn soil maps based on 1:25,000 scale maps (Pásztor et al., 2001). Beside the elaboration of these soil information systems displayed on 1:25,000 scale maps sheets, there have been numerous initiatives for the GIS-based integration of the large-scale (1:10,000) practical soil map, which seems to be unavoidable from various point of views. For example, Takács et al. (2004) developed a soil information system based on the 1:10,000 scale soil maps for 640 km$^2$ area in the eastern "Bihar" region of Hungary. These authors also provided an example for creating a multidisciplinary database of a given small area. The "Tedej" soil information system of 15 km$^2$ comprises topographic sheet, satellite images, aerial photographs, hyper and multispectral images, genetic soil type maps, Digital Elevation Model (DEM), precipitation run-off and similar.


**Fig. VIII.1. The first soil map of Hungary at the scale of 1:900,000, prepared in 1914 by Imre Timkó. Categories distinguished in the legend are the following in order 1. chernozems, 2. chernozems on sand, 3. chernozem on alluvium, 4. brown forest soils, 5. terra rossa, 6. grey forest soil on moving sand, 7. grey forest soil, 8. podzol, 9. salt-affected soil, 10. peat, 11. alluvial soil, 12. alpine skeletal soil.**

## VIII.2 Hungarian Soil Information and Monitoring System (TIM)

The objective of Hungarian Soil Information and Monitoring System (TIM) is the temporal monitoring of soil conditions in order to provide the basis for the legal regulation of the management and protection of soil resources. The soil is sampled yearly and individual parameters are checked with different frequencies ranging from 1 to 6 years (see Várallyay, 2005). The TIM was initiated in 1992, and backed-up in 1994 by Parliament. The activity was developed and is being supervised by a committee of scientist from state institute and practicing soil specialists. The system is based on altogether 1236 points representing the geographical regions of the country as well as different land use types. There are 864 points in agricultural lands, 183 in forests, 189 points such as polluted industrial and urban areas, areas affected by heavy traffic, areas beside military installations and waste storage facilities.

[6] By its completion, in the early 1950s, Hungary was the first country in the World to have such detailed nationwide soil information.

### *VIII.2.1 Kreybig Digital Soil Information System (KDSIS)*

The conversion of soil information originating from the soil maps at 1:25,000 scale to GIS is under construction. There is much more utilizable information originating from this survey, than was processed traditionally and published on the map series and in reports. The surplus information should be exploited by the emerging technologies including the Digital Soil Mapping (DSM) techniques.

The national soil mapping project initiated and led by Kreybig was unique for being a national survey based on field and laboratory soil analyses and at the same time serving practical purposes (Kreybig, 1937). It was carried out between 1935 and 1951 in several stages. When the action was successfully completed, Hungary was the first country in the world to have such detailed soil information for the whole territory. These maps still represent a valuable treasure of soil information. The soil and land use conditions were presented together on the maps. Chemical and physical soil properties of the soil root zone were identified for croplands. Three characteristics were attributed to soil mapping units and displayed on the maps. Further soil properties were determined and measured in soil profiles. The unique feature of the Kreybig method was that one representative and further, non-representative soil profiles occurring within the patch are attached to the soil units of the maps. These profiles jointly provide information on the heterogeneity of the area. The display of non-representative soil profiles indicating within soil unit, unmappable heterogeneity was a unique approach. However, this special feature could not be totally utilized due to the limits of classical cartography. New technologies make the surplus information provided by this methodology exploitable, which can be incorporated into the compilation process of KDSIS.

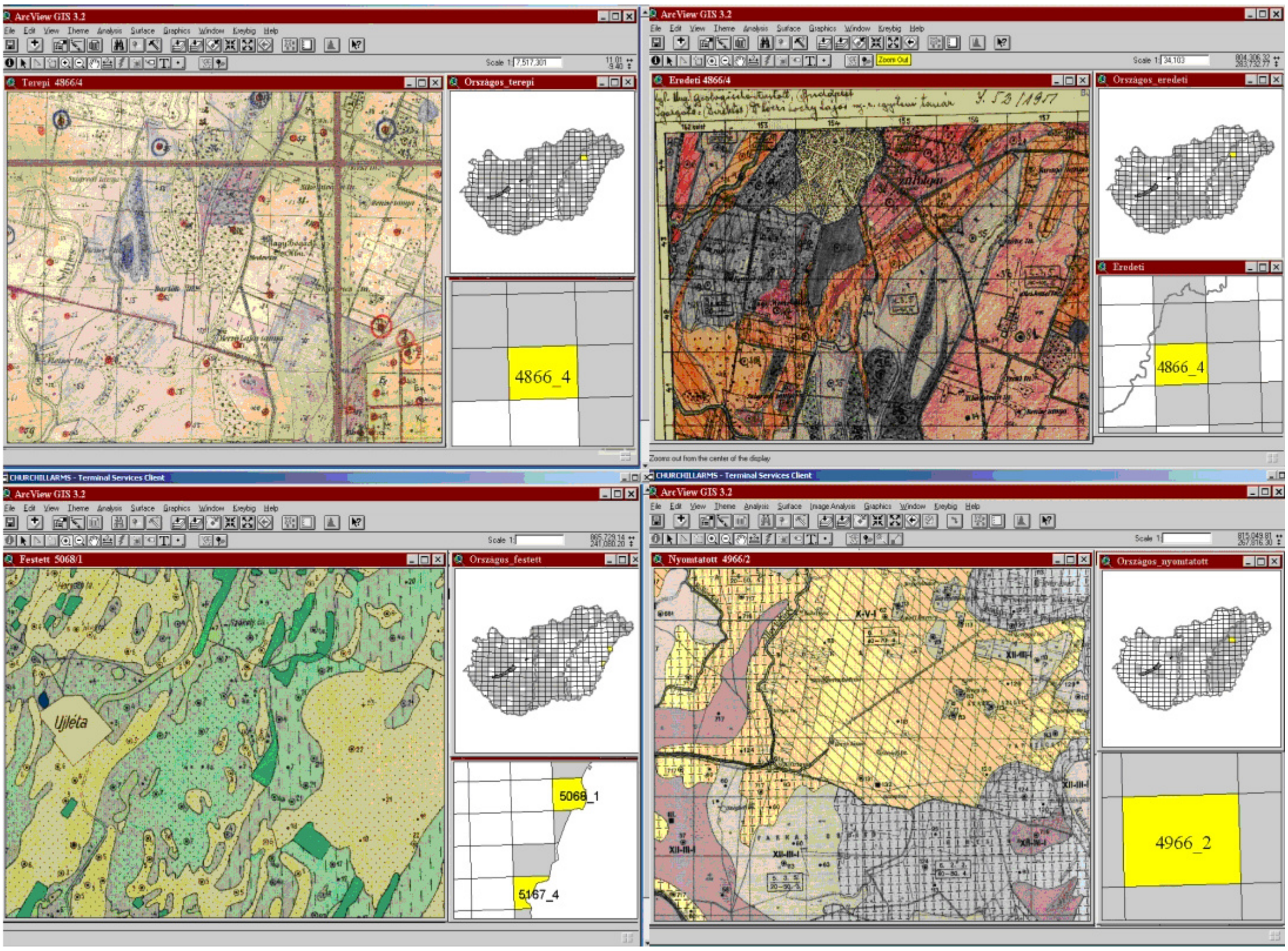


**Fig. VIII.2. The steps of compiling map sheets from original field sheets (Upper left) to working map sheet (Upper right) to hand painted (Lower left) and final printed sheets (Lower right). On the right the country-wide availability of the given processing stage is shown.**

Integration of the Kreybig Digital Soil Information System within appropriate spatial data infrastructure (SDI) and its updating with efficient field correlation makes an inherent refinement and upgrading of the system possible as well as the estimation, measurement of the reliability of the system (Fig. VIII.2). As a result, the raw information processed using traditional methods, together with complementary spatial, digital, environmental data, could lead to a more accurate and, consequently, more reliable system. The KDSIS provides soil information on different level of accuracy – this kind of multilevel feature can be also preserved and even utilized (Fig. VIII.3).

KDSIS provides various opportunities for increasing the spatial and thematic accuracy of mapped soil properties. Spatial refinement of mapping units is mainly based on DSM tools. Contours of soil bodies can be reshaped using more detailed/recent/accurate/reliable environmental co-variables (DEM-derived terrain features, remotely-sensed images, ancillary data collected with non-invasive soil sensors etc.). New soil units can be delineated by integrating Kreybig profile methodology and SDI. Field verification/correlation completed with appropriate data collection, and the inclusion of newly accessed data into KDSIS can also increase significantly the reliability of KDSIS. This verification should be carried out by the reassessment of the originally mapped areas and the profiles accompanied by new samplings at the revisited sites for assessing current soil status. Fieldwork and sampling are supported by field GIS tools which can be used for spatial refinement of soil mapping units. The appropriate management of KDSIS, on the other hand, makes the elaboration of an efficient survey and sampling design possible. Upgraded KDSIS makes the compilation of up-to-date (polygon-based) soil maps possible. Mapping units of the old and new maps may differ due to several reasons: reshaped contours, new soil units with changed attributes may occur on the new map when compared to the old one. Upgraded soil maps display features of current soil status on a higher confidence level, consequently accuracy and reliability of the upgraded map is significantly higher.

Collection of new sampling data at the same revisited sites makes the comparison of archived and newly-surveyed data possible. Thus, changes in soil properties can be identified. This, in one hand, should be recorded in the database, thus, updating it. On the other hand, trends can be identified in soil characteristics and functions, degradation processes can be realized and/or forecasted. New data can serve as reference to the study of anthropogenic effects. Joint management and application of multi-temporal spatial soil information within an appropriate relational database management system (RDBMS) and GIS environment makes KDSIS also a spatio-temporal soil information system.

The applicability of the Kreybig Digital Soil Information System (KDSIS) has been proven by numerous applications. Molnár et al. (1999) used KDSIS in habitat mapping; Farkas et al. (2005) utilized it for the regional extension of results of their modeling work on impacts of different climate change scenarios on soil water regime. Pásztor et al. (2006) employed it in the quantification and mapping of lowland excess water hazard. Very recently, KDSIS was applied as a base information source within the various task packages (land management planning, water management modeling in the territories of future water reservoirs etc.) of the Action Plan on Flood Prevention and Protection for the Tisza River (Szabó and Pásztor, 2004). The fully loaded KDSIS is suggested to serve as a basis for various further soil related expert systems, as well as for the intermediate level of the soil module of the Hungarian SDI (further detailed – 1:10,000 scale – soil maps should give the basis of the Hungarian SDI).

The complete upgrading of KDSIS cannot be carried out by a single research institute and needs extra-institutional co-operation, but the common concept should be elaborated in advance. Nevertheless, the framework of the KDSIS and its upgrading methodology has been worked out. The elaborated environment and methodology is recommended not only in the case of KDSIS, as it could also be applied for the treatment (compilation, refinement, upgrading etc.) of other large-scale SSISs, processing the information collected during 1:10,000 practical soil mappings. Depending on the raw material, certain specifications in the common framework should be adjusted, which also requires some professional reconciliation and co-operation [http://ilzer.rissac.hu/html_5terseg/].

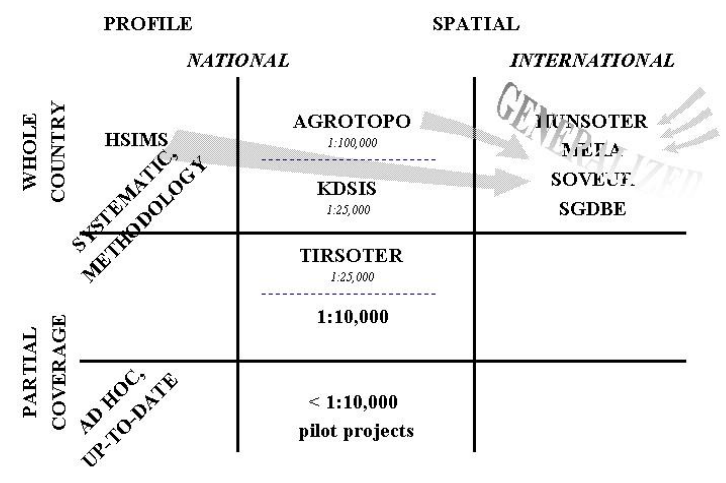


**Fig. VIII.3. The relationship of different Hungarian soil information systems**

### *VIII.2.2 Genetic soil maps of 1:10,000 scale*

In the early 1960's, a system was elaborated by Hungarian soil scientists, soil surveyors and soil-mapping specialists for large-scale soil survey to satisfy the practical needs of soil information for large farming units (state and co-operative farms), which characterized the Hungarian agriculture between 1950 and 1990. Such maps were prepared for about one-thirds of the area of Hungary (about 35,000 km$^2$). The system consists of four main parts: (i) genetic soil map, indicating soil taxonomy units and parent material; (ii) thematic soil maps on the most important physical and chemical soil properties; (iii) thematic maps, indicating recommendations for rational land use, cropping pattern, amelioration, tillage practice and fertilization; (iv) explanatory booklets, including a short review on the physiographical conditions; description of soils, recommendations for their rational utilization, field description of soil profiles and results of field observations or measurements and data of laboratory analyses (Sarkadi et al, 1964; Szabolcs, 1966).


**Fig. VIII.4. Example sheet of 1:10,000 scale genetic soil map the "Magvető" cooperative farm located in the village Dány. In the lower right corner the first column of the legend (color code) indicates soil subtype ranging from "Calcareous humous sand" (first category of 4/1) to "Slope deposits of forest soils" (last category of 40/2). In the central column soil texture category is listed with line pattern ranging from sand to clay. Under this the depth of soil is shown by increasing number of "+" signs. In the right column of legend the parent material is indicated ranging from sand to loessy silt. Numbers with dots indicate the location of soil profiles described.**

These maps were widely and successfully used in Hungary and became an easily applicable scientific basis of intensive, large-scale agricultural production, in spite of the fact that generally these maps were not published in printed form and are available only as manuscripts at the given farming units or at the Plant and Soil Conservation Stations. The large-scale soil-mapping programme was restarted in 1986 within the framework of the National Land Evaluation Programme (AGROINFORM, 1987). The aim of this Programme was to evaluate the agricultural land based on soil information surveyed in a scale of 1:10,000, but was left uncompleted. These huge archives provide appropriate raw material for recent digitally based applications. Spatial soil information systems based on these data could be efficiently used in numerous studies. Szabolcs (1966) described the methodology to be used in the detailed mapping of soils. For example, in the case of salt-affected soils this method at the scale of 1:10,000 can be best illustrated with the set of individual map sheets which might make up a complete soil mapping document.

**Soil map:**
- soil type and subtype (ca 100 categories for the country)
- parent material (56 categories for the country)

- textural class of plough-layer (9 types categories for the country).

**Humus cartograms:**

- thickness of humic layer (6 categories for the country)
- organic matter content (5 categories for the country)

**Soil reaction and $CaCO_3$ content cartograms:**

- pH of plough-layer (7 categories)
- depth of appearance of $CaCO_3$ (6 categories for the country)
- $CaCO_3$ content in the depth of appearance (5 categories for the country)
- hydrolitic acidity of plough-layer (5 categories for the country)
- extent of secondary $CaCO_3$ concentration (4 categories).

**Groundwater cartograms:**

- average groundwater level (5 categories for the country)
- salt concentration of groundwater (6 categories for the country)
- Na percente of groundwater (8 categories for the country).

**Salt-affected properties cartograms:**

- depth of appearance of salt-affected layer (6 categories for the country)
- pH in the depth of appearance of salt-affected layer (3 categories for the country)
- total soluble salt content and exNa% in the depth of appearance of salt-affected layer (8 categories for the country)
- depth of most salt-affected layer (6 categories for the country)
- pH in the depth of most salt-affected layer (3 categories for the country)
- total soluble salt content and exNa% in the depth of most salt-affected layer (8 categories for the country)

The complete documentation of field soil maps contains field records of profile descriptions, results of laboratory analyses and evaluations. The smallest polygon distinguished on large-scale maps of 1:10,000 is 1 ha (Fig. VIII.4).

### *VIII.2.3 1:10,000 scale land valuation system based on D-e-Meter soil fertility index*

The Hungarian official land valuation system is the "*Gold Crown*" which was established purely for land taxation in 1875 by the VII Law as the 20% (from 1924 on the 25%) of the net "*cadastral income*". The latter was defined as "*The (financial) value of the long-term average yield which can be received by usual farming practice minus the expenditures from usual farming practice*" (Sipos and Szűcs, 1992). The drawbacks of the old Gold Crown system are the following (from Lóczy, 2002, based on Sipos and Szűcs, 1992 and Góczán, 1980):

- does not reflect the advances of soil science,
- the fertility of the soils during the past 130 years has changed due to soil improvements and management and is not expressed by the values,
- land cultivation and the genetic resources of plants have changed considerably,
- there is no possibility to separate the ecological and economical factors in the Gold Crown value,
- the importance of transport has increased considerable and, therefore, the old economic valuation is not valid,
- there is an intensification of cropping in the agglomeration zones of cities which is not reflected in the old values.

Logically, there is a need to develop a single integrated modern land valuation system (Fórizs et al., 1971). The new system is based on the D-e-Meter soil fertility index (Gaál et al., 2003). The first step of the calculation of the index is a idea of "*soil scoring*" procedure for specific crops based on the long term yield for specific soil subtypes (for example, "No. 202 Non-Carbonatic Meadow Chernozem", or "No. 131 Ramann Brown Forest Soil") and specific combinations of texture × soil reaction × parent material × organic matter and similar categories. The soil scoring index value is modified according to soil water regime, nutrient status, slope conditions and forecrop and results in the D-e-Meter soil fertility index. The determination of this fertility index is carried out in an on-line GIS system (Vass et al., 2003) based on 1:10,000 soil map. Fig. VIII.5 shows an exemplary special cartogram sheet with the polygons having their respective codes.

Three major databases can be used for calculating this index: (A) AIIR soil property database, comprising real management data (yields, soil properties, nutrient data) from plough layer of ca 80,000 cropland field collected during the intensive cropping period of 1985-1989; (B) Data from a comprehensive network of long term field fertilization experiments carried out at nine locations in different agroecological conditions, but with similar fertilization treatments; (C) Data collected at 10 pilot study areas, which contain soil, topography, photogrammetry coverages and time series of management data. At the moment, the D-e-Meter based land valuation system (Tóth et al., 2006a and 2006b) is being extended from cropland to forest (Bidló et al., 2003) and grassland (Dér et al., 2003, Vinczeffy, 1993) as well. Economic evaluation combined with soil fertility assessment makes up the complete land valuation. A specific region inside Zala County was selected as pilot area where the land valuation system is being tested. Current status of the system can be accessed at [http://www.intermap.hu/demeter/].

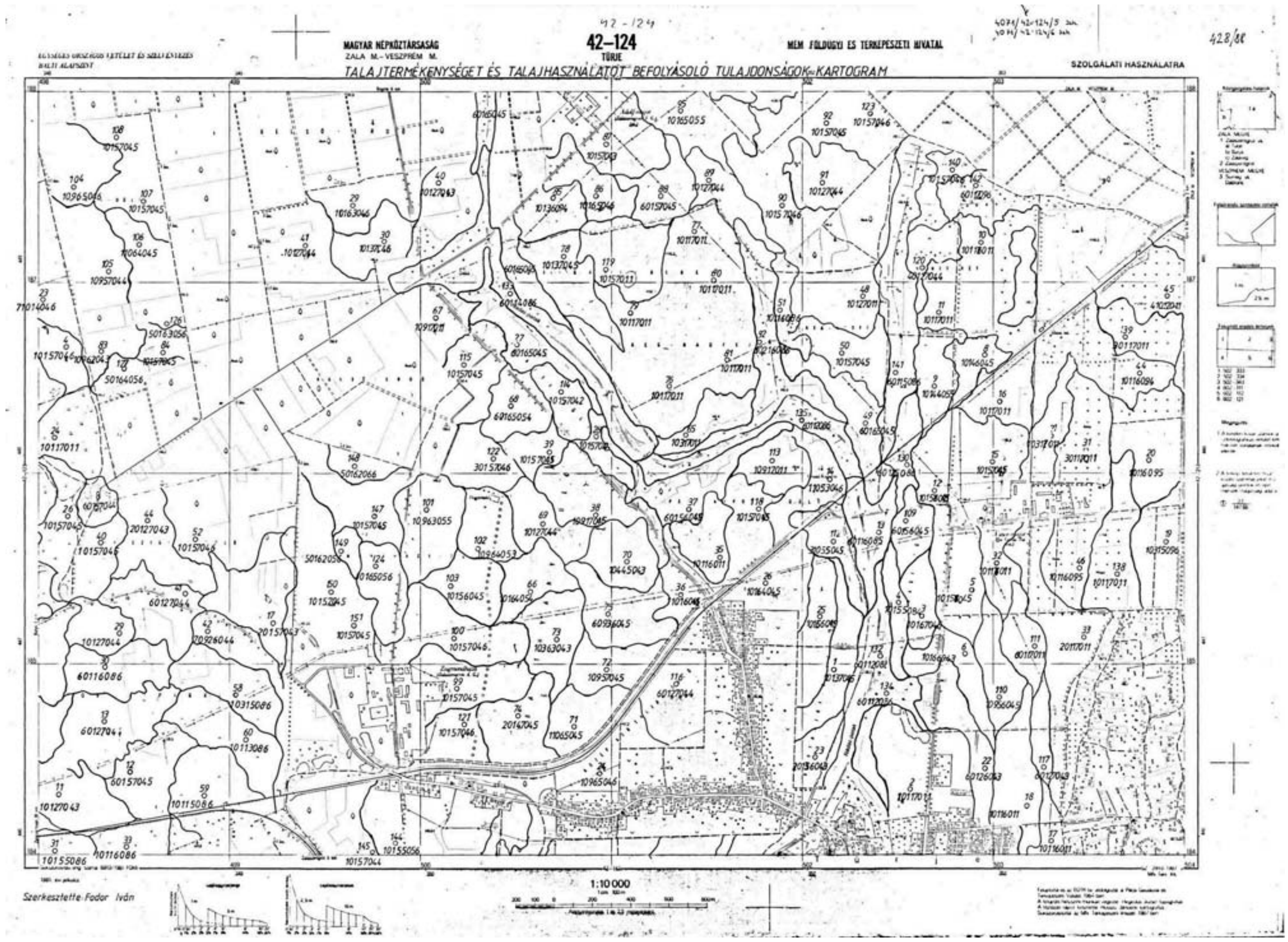


**Fig. VIII.5. 1:10,000 scale special cartogram sheet "Soil properties affecting soil fertility and soil use" coded specially for being used for soil bonitation at the village "Türje". Codes inside the soil polygons show categories of the following properties: grades of erosion/deflation (1 digit), depth of lamellae in sandy soils "kovárvány" (2 digits), stoniness (1 digit), soil depth (1 digit), property affecting unfavourably the sois depth (2 digits), thickness of soil problems (1 digit).**

## VIII.3 Institutional organization of soil information

The highest administrative unit responsible for soil information in Hungary is the Department of Land and Geographical Information at the Ministry of Agriculture and Rural Development (*Földművelésügyi és Vidékfejlesztési Minisztérium Földügyi és Térinformatikai Főosztálya*, FVM FTF). The main tasks of this administrative unit is to look after the national geodesic, cartographical and remotes sensing activity, land registry, soil protection, land valuation, land policy (land property, land use, land consolidation), agrarian information strategy and coordination. It consists of a Department of Land Registry, a Department of Soil Protection and Land Use and a Department of Geodesy, Cartography and Geographical Information Systems

There is an up-to-date cadastral information system in Hungary, which is one of the bases of any soil utilization systems. There is a unified registry, independent from the legal system. It means that all properties, such as houses, flats, plots and agricultural properties are kept in a single registry at 138 Land Registry offices [http://www.takarnet.hu] throughout the country. One advantage of such organisation was the fast reaction to the re-privatisation of cultivated land: it was completely finished in Hungary within five years. The "AGROTOPO" and Kreybig Digital Soil Information System are maintained by the Research Institute for Soil Science and Agricultural Chemisty of the Hungarian Academy of Sciences [http://www.taki.iif.hu].

### *VIII.3.1 Legislation on soil protection*

According to Németh et al. (2005), there are currently nine valid laws, eight government decrees and four ministerial regulations related to the protection of soils. These include Law LV of 1994 on the cultivated soils , Law LIII of 1995 on the general regulations of the protection of environment, Law LIII of 1996 on environment protection, Law LIV of 1996 on forests and the protection of forests, Law XXI of 1996 on regional development, Law XLVIII of 1993 on mining, Law XLIII of 2000 on waste management, Law XXXV of 2000 on plant protection. Among these the single most important for this chapter is the Law LV of 1994 on the cultivated soils. The sections of the Law LV of 1994 on the cultivated soils, for example, are the following:

- Introduction
- Obtaining the property rights
- Use of cultivated soils
- Land consolidation
- Utilization and protection of cultivated soils
- Soil protection, inside which are the following sections found
  - In the Section "Aim of soil protection" it is emphasized that the shrinking of cultivated land acreage should be slowed down. There is a need to safeguard the quality of cropland. Also the law aims the protection against erosion, waterlogging, aridity, salinization, acidification, which protection is expected to be performed by the land user itself.
  - In the Section "Tasks of the state" it is listed that registry, monitoring, legislation, strategy, research as well as creating an administrative authority are the tasks of the state.
  - In the Section "Obligations of the land user" it is listed that such obligations include protection against erosion, acidification, salinization and pollution. Use of certificated amendments is also an obligation of the land user.
  - There is a further Section "Obligations related to land management"
  - In the Section "Land protection authority and its tasks" it is listed that the land protection authority controls soil protection, permits special use of land, provides information on soils as well as imposes fines for illegal actions related to soils.
  - There is a Section "Soil protection fine", in which it is written that the sum of the fine for each hectare can reach between 850 and 18300 times wheat price for kg depending on the illegal action. The fines paid all go to the so called "Soil Protection Fund".
- Closure

## VIII.4 Conclusions

In summary, we can conclude that soil monitoring in Hungrary is active, but only to certain limits and with many financial problems. There is plenty of soil information available, but most of the field observations are old (>20 years). It is difficult to access the detailed 1:10,000 soil maps. All 1:100,000 and about half of the 1:25,000 maps are computerized. The most important information source for plot-scale management, the 1:10,000 map series is covering just two thirds of the country. Soil protection is regulated by law. As an overview, the full range of soil information data sources available in Hungary is shown in Table VIII.1.

**Table VIII.1. The characteristics of the three most popular Hungarian soil databases. KDSIS is Kreybig Digital Soil Information System. The number of "+" signs indicate estimated availability/easiness of use of databases, 5 is the best.**

| *Property* | *Database and scale* AGROTOPO 1:100,000 | KDSIS 1:25,000 | Genetic maps 1:10,000 |
|---|---|---|---|
| SPATIAL RESOLUTION | +++ | ++++ | +++++ |
| THEMATIC RESOLUTION | +++ | +++ | +++++ |
| SOIL PROFILE DATA | none | +++ | +++++ |
| COUNTRYWIDE COVERAGE | +++++ | ++++ | ++ |
| FEASIBILITY OF UPGRADING | none | +++(+) | +++++ |
| DEGREE OF DIGITAL PROCESSING | +++++ | +++(+) | +(+) |
| DATA MANAGEMENT | +++++ | +++++ | ++++(+) |

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# IX. Overview of soil information and policies in Serbia

Dragana Vidojević[1] and Maja Manojlović[2]

1 Ministry of Science and Environmental Protection,
Environmental Protection Agency,
Ruže Jovanovica 27, 11 160 Beograd, Republic of Serbia
Tel: +381 11 2413 966; Fax: +381 11 3809 524
dragana.vidojevic@sepa.sr.gov.yu

2 Faculty of Agriculture, University of Novi Sad,
D. Obradovica 8, 21000 Novi Sad, Republic of Serbia
Tel.: + 381 21 450 762
majacuv@polj.ns.ac.yu

**Summary**

*The soils in Serbia are extremely heterogenic, as a result of the great heterogeneity of geological base, climate, vegetation and pedo-fauna. Agricultural land in Serbia covers ~66% of the total area. Distribution of the agriculture land according to the main categories of the land use shows high proportion of arable land (65.4%). The national system of soil classification has passed through different phases of development. The classification is based on the genetic principles and does not correspond to WRB criteria. Soil monitoring in Serbia is performed through a number of projects implemented by different scientific and professional institutions in different parts of the country, which resulted in the existence of several databases. However, it is still impossible to present the entire territory of Serbia due to various harmonisation problems. Although the Law on Agricultural soils was adopted in spring 2006, legislation related to monitoring the quality and protecting the soil in Serbia is still underdeveloped. A set of bylaws are now being prepared which will define in more detail the program of continuous soil monitoring and data collection in a harmonized manner. A more thorough overview of the status, introducing systematic quality control and creating a centralized database at the national level is necessary for setting goals in the field of preserving the soil in Serbia.*

## IX.1 Geographic Characteristics

The Republic of Serbia covers the north-west part of the Balkan Peninsula, in the southern part of the Central and East Europe Region. Serbia extends between 41° 52’ and 46° 11’ north latitude and between 18° 06’ and 23° 01’ east longitude and covers the area of 88,361 km$^2$. In respect of the administration system, the Republic comprises central Serbia and two autonomous regions: Vojvodina (21,506 km$^2$) and Kosovo & Metohija (10,887 km$^2$). Since June 1999, AP Kosovo & Metohija has been under the jurisdiction of UN Interim Administration Mission in Kosovo (UNMIK). According to its geographic position and natural characteristics, Serbia is a country situated in the Central-European, Balkan, Pannonian, and Danube region.

### *IX.1.1 Land resources*

The great heterogeneity of geological base, climate (nine edaphic climatic regions), vegetation and paedo-fauna has resulted in the formation of extremely heterogenic soils in Serbia. In each of the respective regions, several soil types are represented and their combinations reflect the general characteristics of these units.

### *IX.1.2 Land use*

Serbia has 5,113,307 ha of agricultural land, which is 66% of its total area. Arable land and gardens dominate with by far the greatest areas under agricultural production (3,343,916 ha or 65.4%). In the territory of Central Serbia, of the total agricultural area of 3,321,148 ha, arable land and gardens account for 1,762,094 ha and these amounts to 53.1%, while in the territory of Vojvodina, out of 1,792,159 ha of agricultural area, arable land and gardens account for 1,581,822 ha (88,3%).

### *IX.1.3 Land quality classes*

As for agricultural utilization of soils, the potential of Serbian soils is classified into eight classes, where the first four classes are higher-quality soils and classes 5-8 cover soils mainly unfit for agriculture (Table IX.1). As for the whole of Serbia, the distribution of arable and non-arable land is almost identical. Intensive agricultural production is least restricted in Vojvodina and most restricted in Kosovo and Metohija. The latter territory, similar to that of central Serbia, has a wide range of natural fertility in narrow geomorphological units.

**Table IX.1. Land quality classes in Serbia.**

| *Soil class* | *$km^2$* | *%* |
|---|---|---|
| 1 | 11,650 | 14.4 |
| 2 | 9,357 | 11.6 |
| 3 | 10,522 | 13.0 |
| 4 | 8,682 | 10.8 |
| Arable | 40,211 | 49.8 |
| 5 | 11,073 | 13.7 |
| 6 | 20,144 | 25.0 |
| 7 | 8,069 | 10.0 |
| 8 | 1,178 | 1.5 |
| Non-arable | 40,464 | 50.2 |
| Productive | 80,675 | 91.3 |
| Infertile | 7,686 | 8.70 |
| ***Total*** | **88,361** | **100** |

### *IX.1.4 Causes of soil degradation*

The occurrence and progress of erosion processes is one of the major causes of soil degradation and its deteriorated quality. It is estimated that erosion processes (of various degrees) affect up to 80% of agricultural soil in Serbia. While, in central regions and the hilly-mountainous regions, the predominant type is water erosion, the predominant type of erosion in Vojvodina is the wind erosion. Approximately 85% of agricultural soil in Vojvodina is affected by wind erosion with an annual loss of over 0.9 ton material per ha. Soil quality is also affected by uncontrolled and inadequate dumping of waste. Large land areas in the vicinity of industrial complexes (Bor, Pančevo, Novi Sad, Smederevo, Belgrade and Kragujevac) are contaminated with various pollutants discharged from industrial facilities.

Causes of problems:

- Lack of legislation for the control of hazardous substances in soil;
- Low level of environmental awareness of agricultural producers;
- Land use patterns encouraging soil erosion;
- Widespread use of leaded petrol.

## IX.2 Soil Survey

The status of soil survey in Serbia and Montenegro has been described earlier (Protić et al., 2005), therefore only a short overview on soil classification and mapping in Serbia will be given in this report.

### *IX.2.1 Soil Classification*

Classification and cartography in Serbia has passed through different phases of development. The first classification of soils of the Kingdom of Yugoslavia, was prepared by Stebut (1927). Other classifications, based on the genetic principles, were published subsequently by Neugebauer et al. (1963) and Filipovski et al. (1964). In order to facilitate international communication, the national system of soil classification in Yugoslavia was adapted to the international classification valid at that time in Europe (Škorić et al., 1973; 1985). That classification is still accepted and in use in Serbia, but unfortunately does not completely correspond to WRB criteria.

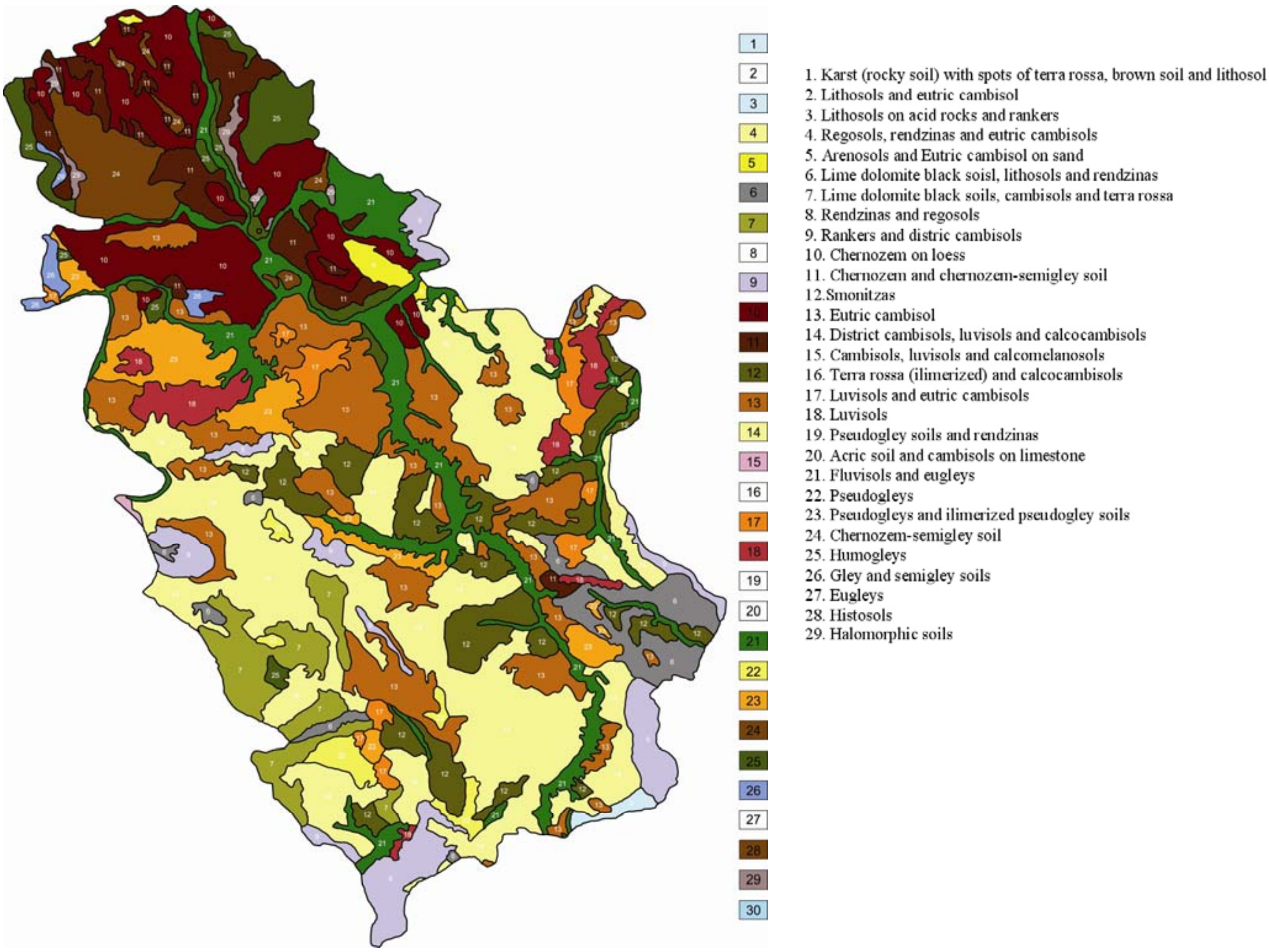


**Fig. IX.1. Soil map of Serbia (1:2,000,000).**

### *IX.2.2 Soil mapping*

The first two soil maps of Kingdom of Yugoslavia, at the scale 1:3,500,000 and 1:1,200,000, were compiled by Stebut (1926; 1931). During the period from the late 1970s to mid 1980s, soil mapping in Yugoslavia was intensively conducted resulting in:

- The soil map of Yugoslavia (in a scale 1:1,000,000);
- The soil map of the Vojvodina Province (1:100,000);
- The soil map of Yugoslavia (1:50,000).

In 1983, the financing of the project in Serbia was stopped, resulting in about 700,000 ha of unmapped soils (region of South Serbia). Fig. IX.1 shows the soil map of Serbia (1:2,000,000), which was made on the basis of the classification of soils of Yugoslavia (Škorić et al., 1985), by reducing and generalizing the existing soil maps prepared in larger scales. Table IX.2 lists the soil types found on the territory of Serbia.

### *IX.2.3 Digitalized soil maps*

At present, there is no digital soil map of the whole country; only the soil map of Vojvodina (Fig. IX.2) has been digitised (Benka and Salvai, 2006). The basis for constructing the soil map was the Soil Map of Vojvodina published by the Institute of Agricultural Research in Novi Sad in 1971. The map is made in a scale 1:50,000 and the Vojvodina territory is presented on 60 sheets. Digitising was carried out on the basis of the scanned sheets of this map, which were previously geo-referenced. During the geo-referencing, deformations caused by the effect of moisture and temperature on the map were eliminated, as well as potential errors made in the course of scanning.

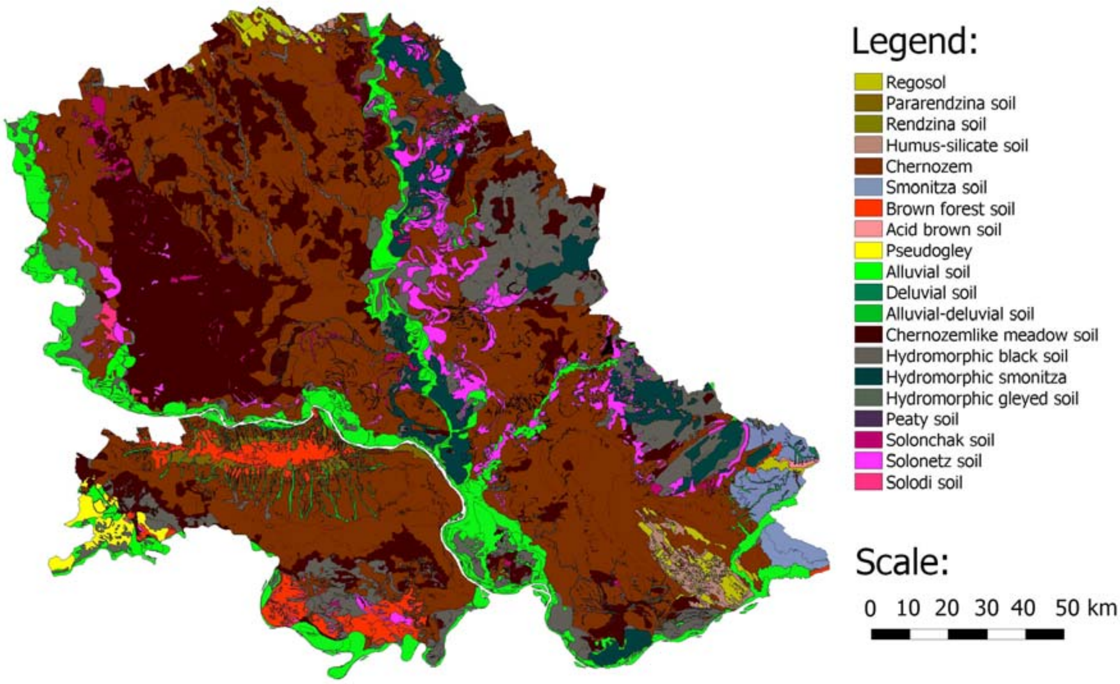


**Fig. IX.2. The soil map of Vojvodina based on classical map in scale 1:50,000 (Benka and Salvai, 2006).**

**Table IX.2. Soil types found on the territory of Serbia.**

| ***Soil type*** | ***Area (ha)*** |
|---|---|
| Lithosol | 107,000 |
| Aeolian sands (Arenosol) | 86,000 |
| Rendzinas | ~ 527,000 |
| Black earth on limestone (Calcomelanosol) | ~ 155,000 |
| Humus-siliceous soil (Ranker) | 572,000 |
| Chernozem (Phaeozem) | 1,200,000 |
| Smonitza (Vertisol) | 780,000 |
| Brown soil on limestone (Calcocambisol) | ~ 350,000 |
| Eutric brown, typical- brown forest soil (Eutric Cambisol) | 560,000 |
| Dystric Cambisol | ~ 2,280,000 |
| Illimerised soil (Luvisol) | ~510,000 |
| Pseudogley (Planosol) | 538,000 |
| Podzol | ~ 17,000 |
| Alluvial soil (Fluvisol), Meadow soil (Humofluvisol), Hydromorphic black earth and Marsh-gley (Humogley, Eugley) | ~ 760,000 |
| Solonchak and Solonetz | 233,000 |
| Peaty soil (Histosol) | ~ 3,000 |
| Deposol | ~ 50,000 |

Potential applications of such GIS include constructing thematic maps showing the spread of particular parameters related to soil types. In the combination with other GIS layers, it is possible to obtain new layers that are the result of the intersection or difference of these layers connected to the corresponding databases.

## IX.3 Soil Databases

Serbia lacks monitoring and integrated soil information system. There are many bottom-up uncoordinated activities such as setting up of local or regional databases, but these may cause future problems with the database compatibility. The state of soil in Serbia has been evaluated by different project teams in various parts of the country.

### *IX.3.1 Soil fertility and harmful and hazardous substances in Serbia*

The soil fertility project was carried out on the entire territory of Vojvodina (1.6 mill ha; 1600 samples) in 1993, and in parts of central Serbia in 1997 by the Institute of Soil Science (2005), Belgrade and Institute of Field and Vegetable Crops, Novi Sad (Čuvardić et al., 2004; Sekulić et al., 2005). In 2003, soil monitoring continued in central and western Serbia on another 250,000 ha. Georeferenced soil samples were collected from every 1000 ha (10 $km^2$), in a grid pattern with precisely determined coordinates. One composite sample, which represents an average sample of 25 soil samples from the depth of 0-30 cm, was taken at each location.

The program included determination of:

- **Acidity** ($pH_{kcl}$ in soil), **carbonates** ($CaCO_3$), **quantity of humus and presence of phosphorus and potassium** in soil which are easily accessible to plants;
- **Microbiological activity of soil** (total number of bacteria, dehydrogenic activity of soil, the number of ammonificators, free nitrogen-fixing bacteria, azotobacteria, fungi and actinomycetes);
- **Heavy metals and micro-elements concentration** (As, B, Cd, Cr, Cu, F, Hg, Ni, Pb, Zn);
- **Remains of 17 active ingredients of pesticides in soil** (4,4 DDD, 4,4 DDE, 4,4 DDT, Aldrin, alfa HCH, beta HCH, Lindan (gamma HCH), Diazinon, Dieldrin, Endrin, Endrin aldehyde, Heptachlor epoxide, Alachlor, Atrazin, Prometryne, Sinazine, Terbutryn).

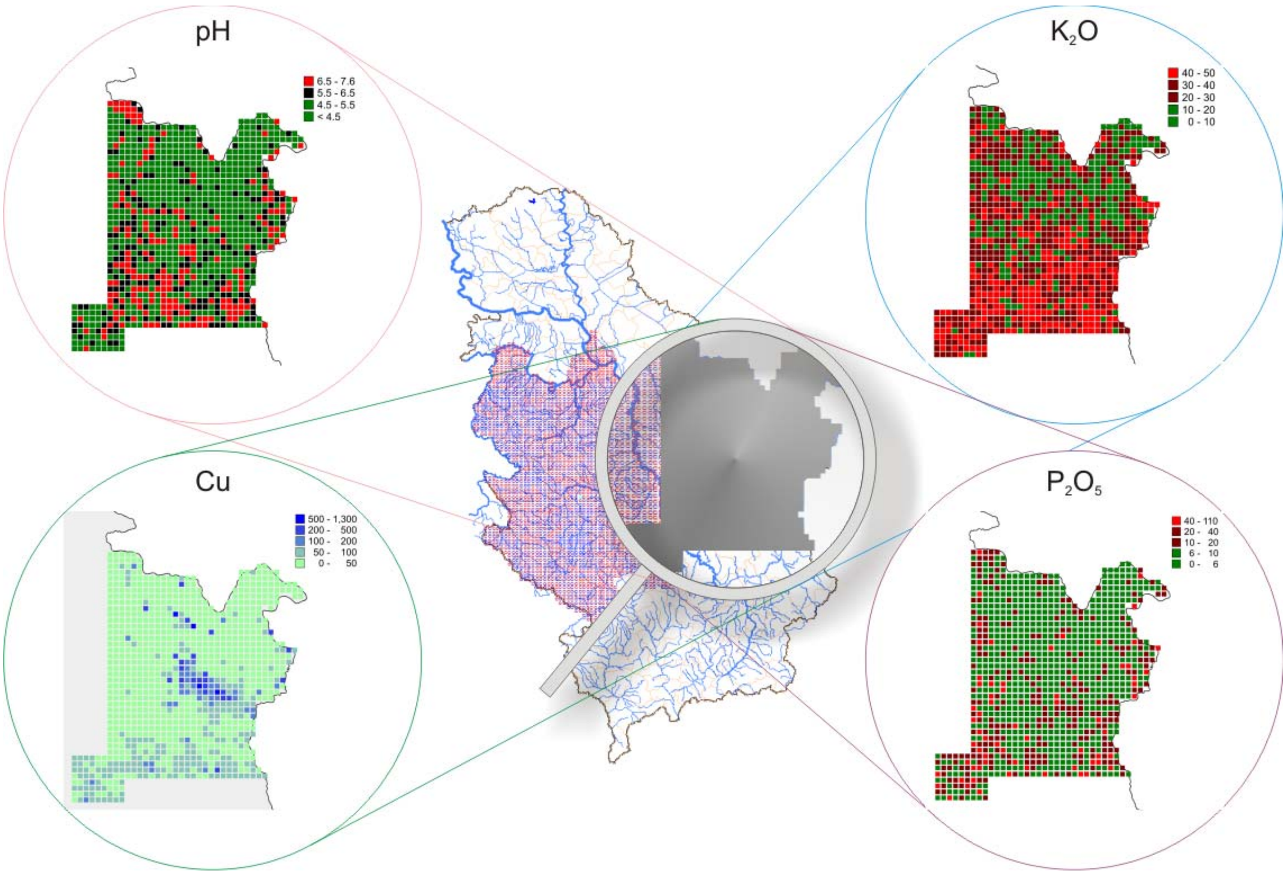


**Fig. IX.3. Soil quality of Central Serbia (pH in KCl, $K_2O$ mg/100g, $P_2O_5$ mg/100g, Cu mg/kg).**

The results of the Project describe the soil of Central Serbia (Fig. IX.3):

- The examination of nutrients ($P_2O_5$, $K_2O$), humus and carbonates supplies in soil as well as soil acidity show an unsatisfactory state of these soil fertility indicators. The types of soil with higher acidity, lower concentration of easily accessible phosphorus and potassium and smaller quantity of humus include: Eutric Cambisol and Luvisol in Central Sumadia, also partially present in the Kolubara basin where Eutric Planosol dominates whereas Cromic Luvisol, Eutric Planosol and Dystric Cambisol on different substrata dominate in the eastern Serbia.
- On the basis of recent research of soil in Serbia and knowledge of dangerous and harmful substances and their accessibility to plants, it can be stated that food production can develop with no high degree risks in approximately 93% of researched areas of Serbia. In 13% of researched areas, food production should be organized with a reduced risk (the choice of cultures) and/or periodical /permanent inspections of soil quality and plants along with appropriate agritechnical measures which would cause preventive reduction of potential as well as real risk in the first place.
- The research of microbiological characteristics shows that certain parameters have extremely irregular distribution in comparison to the observed data base. It was observed that fungi presence in soil is far more stable than dehydrogenic activity.
- No great deviation was observed in the remains of 17 pesticides on soil. The occurrence of DDT and its metabolites and Lindan gHCH is connected to their use in forest protection whereas slightly higher values of the remains of triazine active ingredient were observed in the soils used in farming. According to the recent findings there is no soil pollution from the group of analyzed pesticides remains in almost 99% of examined samples.

The recent research shows that variations of certain parameters are caused by the increase of their natural concentration, the phenomenon also existent in other parts of the world. However, higher concentration of dangerous and harmful matters in certain samples, increased acidity of soil and their joint influence on increasing risk of plants adoption certainly merit our attention and further research.

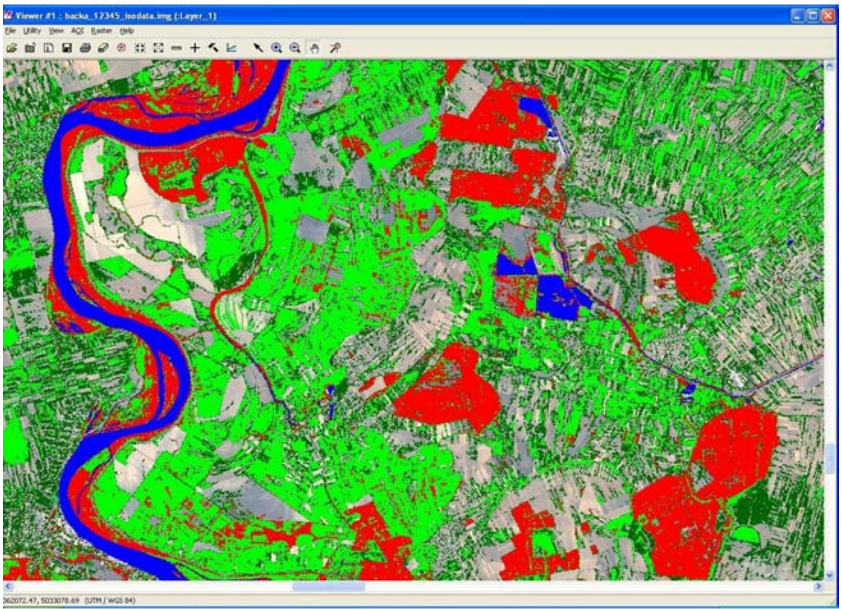

**Fig. IX.4. Landsat TM satellite image classified to main crop and land use types (Provincial Secretariat for Agriculture, Water economy and Forestry & Faculty of Technical Sciences, Novi Sad).**

### *IX.3.2 Database of fertility properties of soils in private ownership*

The scientific basis of the Soil Fertility and Fertilizer Use Control System was established in 1980 and it was legislated in 1985. The System encompasses the control of all factors that determine soil fertility and fertilizer action, i.e., how soil affects the growth, development and yield of crops and which measures must be undertaken to ensure high, stable and economic yields and adequate protection of the biosphere (Manojlović, 1986). Because of the economic crisis that existed in the country during the last 15 years, the System was not fully exploited. In 2002, a campaign was launched to conduct soil analyses in the private sector free of charge (Sekulić et al., 2003). In Vojvodina, the campaign was organized by the Secretariat of Agriculture of the Vojvodina Province and the Institute of Field and Vegetable Crops, Novi Sad. In Serbia, the soil monitoring system was realized by agricultural extension service through the project funded by Ministry of Agriculture, Forestry and Water Resources of the Republic of Serbia.

Since 2002, more than 83,000 samples were collected and analyzed. Last year, 20% of the taken samples were georeferenced and stored in the database. In 2006 the proportion of georeferenced samples will be higher. The database contains the following information:

- **Owner, cadastar parcel, land use, crop**;
- **pH value** in soil suspension with sodium chloride, determined potentiometrically;
- **$CaCO_3$ content** – with a calcimeter after Scheibler;
- **Humus content** – by the method of Tjurin;
- **Available phosphorus** (extraction with ammonium lactate) – AL method; phosphorus content by the blue method in a spectrophotometer;
- **Available potassium** (extraction with ammonium lactate) – AL method; potassium content determined flame photometrically.

### *IX.3.3 Project "New technologies in agricultural soil management in Vojvodina"*

Currently, the project "*New technologies in agricultural soil management in Vojvodina*" is being conducted with the general objective of managing soils in Vojvodina, especially agricultural soils. It is of particular significance because over 90% of the territory of Serbia is privately owned. The project is based on the most modern technologies (Fig. IX.4), which include remote detection and image processing software, image content classifying software and its distribution to end users. The result of the project is a complex information system which enables managing reforms in space. An information system like this is necessary for documented agricultural production, but it will also enable policy makers to obtain other important information, such as yield estimate, vegetation status, etc.

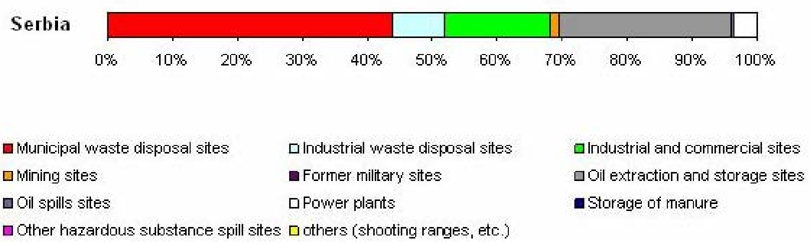


**Fig. IX.5. Soil polluting activities from localized sources as % of total sites where site investigation has been completed.**

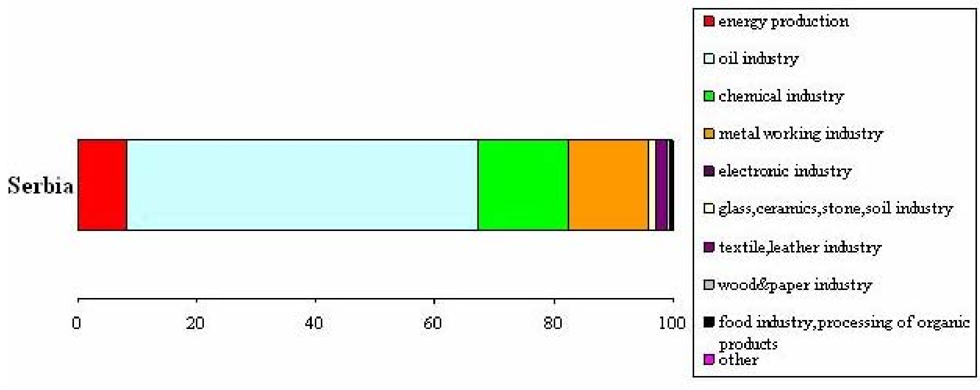


**Fig. IX.6. Breakdown industries responsible for local soil contamination as % of total.**

### *IX.3.4 Soil contamination*

In 2006, the Environmental Protection Agency set up a database of the contaminated areas in the territory of Serbia. The database covers the localities that were identified before 2005 and have not been georeferenced. Considering the manner in which contaminated areas are managed, the following conclusions can be made:

- Management of contaminated sites in Serbia is not institutionalized and it is not possible to completely quantify the progress in this field at the national level. There is no specific methodology that can be used for defining contaminated sites in Serbia. Presented contaminated localities are identified on the basis of laboratory analysis of soil and groundwater in the near vicinity of localized pollution sources and their long term presence.

- Preliminary studies are conducted at most of the identified contaminated sites in Serbia.
- The greatest number of registered sources of localized soil pollution are related to municipal waste disposal sites, oil extraction and storage sites, industrial and commercial sites (Fig. IX.5). The municipal waste disposal site database was updated in 2005. There are 164 municipal waste disposal sites on the territory of Serbia which present a potential source of soil and groundwater pollution.
- The greatest part of the identified polluted soil localities within industry (Fig. IX.6) belongs to the oil industry (59.2%), followed by the chemical industry (15.2%) and the metal working industry (13.3%).
- The database does not include military localities.

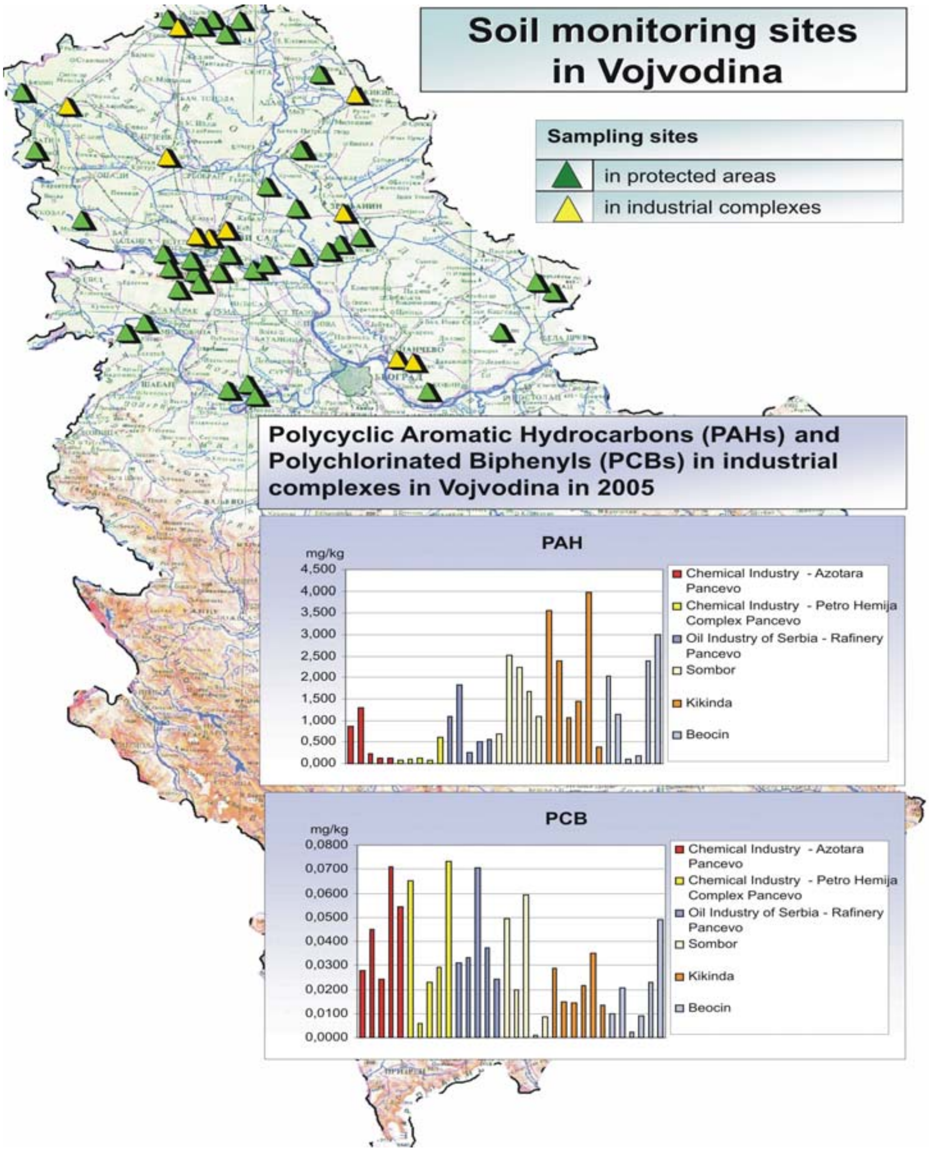


Fig. IX.7. Soil monitoring sites in Vojvodina.

# IX.4 Soil monitoring

### *IX.4.1 Localities under various kinds of protection*

The project "*Environmental quality monitoring in the territory of Vojvodina – non-agricultural land*" (Fig. IX.7) is a systematic research activity that is conducted by the Institute of Field and Vegetable Crops in Novi Sad. For monitoring of soil quality in Vojvodina, locations under various kinds of protection were chosen in order to follow the impact of pollution which is a consequence of NATO bombing of industrial complexes in Vojvodina and their state was observed for three years. The database consists of the findings made by the Project with the georeferenced localities examined in 2002, 2003, and 2004.

### *IX.4.2 Industrial localities*

Within the Project "*Environmental quality monitoring in the territory of Vojvodina – non-agricultural land*" the quality of non-agricultural land of larger towns with developed industry was monitored in the territory of Vojvodina, specifically in Pančevo, Sombor, Kikinda, Zrenjanin and Beočin. The results are available in digital format with georeferenced sampling localities. Basic chemical properties (pH, $CaCO_3$ and humus) and soil fertility in the most important biogenic elements (N, P and K), content of heavy metals and microelements, as well as organic pollutants (polychlorinated biphenyls – PCBs, and polycyclic aromatic hydrocarbons – PAHs) were examined at each location.

Findings of the examination of heavy metal content in non-agricultural land of industrial zones in 2005 demonstrate that their origin in the soil is primarily geochemical, namely that non-agricultural land of the Vojvodina's industrial zones are not contaminated by heavy metals. At the two localities of cement plant in Beočin, the soil is contaminated by nickel of anthropogenic origin, and the soil in the area of the battery factory in Sombor is contaminated by the lead of anthropogenic origin.

Due to the absence of legislation that governs the Maximum Allowed Concentration (MAC) for polychlorinated biphenyls and polycyclic aromatic hydrocarbons in soil, the comments on the findings were made applying the German MAC criterion. PCB contamination is the most intense in the area of Pančevo. Applying the German MAC criterion for PCBs of 0.05 mg/kg, this value is exceeded in 33% samples of soil in Pančevo and only one sample in the vicinity of the battery factory in Sombor. The average PAH content is highest in the soils of Kikinda and amounts to 2.138 mg/kg of soil. Of the total number of samples, 76.7% of the examined soil samples were contaminated by PAHs in the quantity that exceeded the MAC. This practically means that the soil can potentially be a source of underground water contamination by polycyclic aromatic hydrocarbons.

### *IX.4.3 Urban soils*

In the territory of Serbia, examination of soil quality in urban zones is conducted in some of the larger towns and cities and it is mainly associated with accidents. In the administrative borders of the City of Belgrade, systematic examination of the soil condition has been conducted since 1999 to determine the contamination level and potential risk to population health. The findings are available in digital format with georeferenced sampling localities.

The laboratory testing of soil contamination in the territory of Belgrade is conducted by the City Institute for Public Health. The processed soil samples are analyzed for the content of following parameters: pH value, humidity, nitrogen, phosphors, sulfates, arsenic, nickel, chrome, zinc, copper, cadmium, lead, quicksilver, pesticides, polycyclic aromatic hydrocarbons (PAH), mineral oils, and polychlorinated biphenyls (PCBs). The Program of survey of soil pollution on the territory of Belgrade is directed towards:

- Soil in the zone of sanitary protection of drinking water sources;
- Soil in city parks and other facilities;
- Soil in the vicinity of industrial complexes;
- Soil in the vicinity of important motorways.

### *IX.4.4 Forests soils*

Within the "Monitoring of the health status of forests in the Republic of Serbia", the annual report of the ICP Forests 2003, The Forest Administration of the then Ministry for Natural Resources and Environment Protection accepted the program of surveying the soil in the 16×16 km grid at 103 bioindication points (Fig. IX.7), the implementation of which was entrusted to the Faculty of Forestry in Belgrade. In all selected land plots, paedological profiles were opened and soil samples were taken from fixed depths, from the following layers: organic, 0-5 cm, 5-10 cm and 10-20 cm, as well as from the depth of 20-40 cm and further to the holding substrate, with the aim of making the full characterization of soil. As in 2003, the sample plot grid of 16×16 km did not cover all the most important forest ecosystems in Serbia. To solve this problem, in 2004, another additional plot grid was installed of 4×4 km grid.

During 2003/2004, in the above network of points, according to the ICP methodology, chemical analyses were conducted for organic and mineral layers of soil. Besides the chemical analyses, also conducted were the analyses of the mechanical composition of soil. The findings of these analyses for deeper layers allowed more precise identification of soil types, both according to the national and FAO classification.

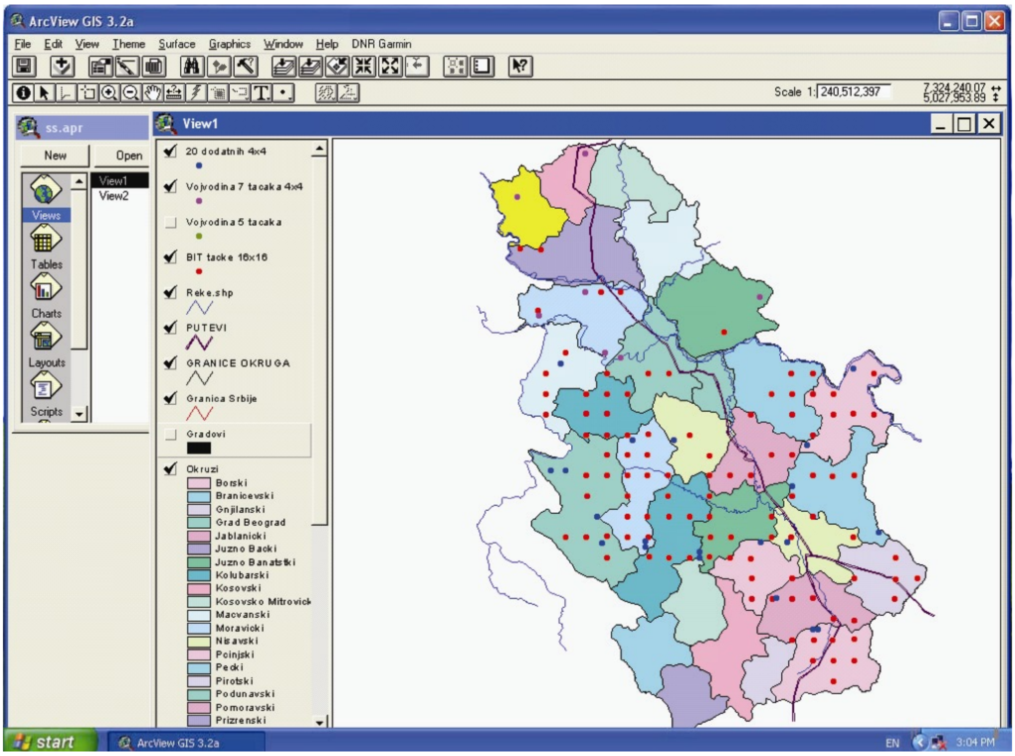


**Fig. IX.8. Sample plots in Serbia (GIS application).**

## IX.5 Legal and institutional framework for soil management

The body of environmental legislation in Serbia comprises more than 100 laws and regulations. Legislative, executive and judicial powers are mostly exercised within the legally prescribed scope of competence of the republic's authorities. According to the law, certain competences are delegated to the autonomous province and the local government.

- **The Ministry of Science and Environmental Protection –** Directorate for Environmental Protection (DEP) has the key responsibility in the field of environmental protection.
- **The Environmental Protection Agency (EPA)** was established in 2004 as an institution within the Ministry for Science and Environment. The main function of the EPA includes development, harmonization and management of the national environmental information system and monitoring of the state of the environment.
- **The Ministry of Agriculture, Forestry, and Water Management** is responsible for the protection of soil, water resources, and forests. Directorate for agricultural soil manages agricultural soil (state property), carries out inspections and professional tasks regarding agricultural soil, sets up and develops the information system on agricultural soil of the Republic of Serbia.
- **The Ministry for Mining and Energy** provides information on mining activities, particularly with respect to impact of mining activities on soil pollution.
- **The Republic Geodetic Authority** is a specialized organization carrying out technical and administrative tasks related to state survey, land cadastre, real estate cadastre, utilities cadastre and registration of real estate rights, their maintenance and updating, as well as other assignments, as defined by the law.

The new legal framework for environmental protection was introduced in Serbia in 2004 by the Law on Environmental Protection, Law on Strategic Environmental Assessment, Law on Environmental Impact Assessment and Law on Integrated Pollution Prevention and Control (Official Journal of Republic of Serbia, No. 135/04).

Significant issues addressed by the ***Law on Environmental Protection*** include the management and protection of natural resources, measures and conditions of environmental protection, environmental programs and plans, industrial accidents monitoring and information system, reporting, financing of environmental protection, inspection services and fines. The new laws are harmonized with the EU Directives on Environmental Impact Assessment (85/337/EEC), Strategic Impact Assessment (2001/43/EC), IPPC (96/61/EC) and Public Participation (2003/35/EC).

The ***Law on Environmental Protection*** defines criteria for the establishment of endangered environment status, as well as the regime for its rehabilitation and remediation. The status of particularly endangered environment as well as priority areas for the implementation of rehabilitation and remediation actions are determined by the Government. The regulation which will define the mentioned criteria is in preparation.

In the ***Law on Environmental Protection*** there is a part related to Protection of Natural Resources which includes Article 22 related to Soil Protection.

No specific legislation exists in Serbia regarding soil and groundwater contamination and criteria for remediation. There are only ***Regulations on permitted amounts of hazardous and harmful substances in soil and water for irrigation and methods for their testing***. *(Official Journal of Republic of Serbia, No. 23/94)* which regulate soil quality in terms of the hazardous chemical substances content.

The new ***Law on Agricultural Soil*** *(Official Journal of the Republic of Serbia 62/2006)* regulates planning, protection, management and usage of agricultural soil as well as inspection of law application. The Directorate for Agricultural Soil is formed by this law as a part of the Ministry of Agriculture, Forestry and Water Management.

The new ***Law on Organic Production and Organic Products*** *(Official Journal of the Republic of Serbia 62/2006)* regulates the production of agricultural and other products by methods of organic production, storing, transport, labeling and organic product flow, certification and recertification for organic products along with other issues concerning organic production.

### *IX.5.1 Plans and strategies*

The ***National Environmental Strategy*** (NES) was developed in 2005 with the objective to guide the development of modern environmental policy in Serbia over the next decade. The NES was followed by the Environmental Action Plans that provides a detailed implementation plan for the next five years. Furthermore, the NES facilitates the EU approximation process in Serbia.

### *IX.5.2 Environmental policy objectives concerning soil*

- Short-term policy objectives 2006-2010: to harmonize national soil legislation with the EU environmental legislation.
- On-going policy objectives 2006-2015: to achieve 20% reduction of land endangered by soil erosion by introduction of effective erosion control measures.
- Medium-term reforms of the monitoring and reporting system 2011-2015: to introduce regular monitoring of heavy metals and pesticides concentration in soil.

## IX.6 Outlook

More and more attention is being paid to the protection of soil in Serbia. Since 1992, the basic legal document covering this area was the **Law on Agricultural Soil** (Official Journal of the Republic of Serbia 49/92 ), which dealt with protection, utilization and management of agricultural soil as a natural resource and a resource of national interest. This year the new Law on agricultural soil was passed (Official Journal of the Republic of Serbia 62/2006), in which the concept of sustainable development was completely implemented. There are now mechanisms for those who damage an agricultural soil after a period of utilization, to return the soil to its former condition through the process of recultivation. This will significantly reduce the area of damaged agricultural soil.

- Soil databases exist in a several institutions, but they are not interlinked and most of data is not digitalised. This has serious limitations for active soil information use at the national scale and especially internationally.
- National soil classification system should be harmonized with WRB criteria.
- There are still 700,000 ha of unmapped soils in Serbia.
- The total area of the country is still not covered by digital cadastre.
- The development of large-scale soil surveys together with the Soil Information System should be supported as the basis for the introduction of the system of decision making and land management in Serbia.

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# X. Overview of soil information and soil protection policies in Slovenia

Petra Krsnik[1], Marko Zupan[2] and Franc Lobnik[2]

1 Environmental Agency of Republic of Slovenia,
Vojkova 1b, 1000 Ljubljana, Slovenia
Tel.: + 386 1 478 41 84; Fax: + 386 1 478 40 52
petra.krsnik@gov.si

2 University of Ljubljana, Biotechnical Faculty, Centre for Soil and Environmental Science,
Jamnikarjeva 101, 1000 Ljubljana, Slovenia
Tel.: + 386 1 423 11 61; Fax: + 386 1 423 10 88
marko.zupan@bf.uni-lj.si; franc.lobnik@bf.uni-lj.si

**Summary**

*Permanent soil pollution monitoring including soil pollution assessment in Slovenia is mandatory and legislated by the "Act on the Protection of the Environment" (Official Journal, 1993, 2004). Soil pollution assessment activities in Slovenia started after the "Decree on the Input of Dangerous Substances and Plant Nutrients into Soils" and the "Decree on the Limit, Warning and Critical Concentration Values of Dangerous Substances in Soils" (Official Journal, 1996) took effect. Technical procedures including sampling, pre-treatment and laboratory procedures are prescribed by the "Rules on Operation Monitoring of the Input of Dangerous Substances and Plant Nutrients in Soils (Official Journal, 1997). Soil pollution data are collected by soil pollution assessment which is on going project (ROTS). Soil pollution data resulting from systematic sampling exist for approximately 34% of Slovenian territory according to predefined sampling pattern in Resolution of National Environmental Action Plan (Official Journal, 2006). In the coming years, soil sampling and analyses will be repeated on selected sites, and soil pollution assessment and monitoring will run parallel. Nearly 700 soil pollution assessment sampling points are predefined for Slovenia and between 150 to 300 sites will be necessary for soil pollution monitoring including remediation sites.*

## X.1 Slovenia in general

Slovenia is situated in the Central Europe, on the south side of the Eastern Alps (Fig. X.1). It is also a Mediterranean country, although it has only about 46 km of coast. Neighbours of Slovenia are Italy, Austria, Hungary and Croatia. The area of Slovenia is about 20,000 km$^2$ and it has approximately 2 million inhabitants.

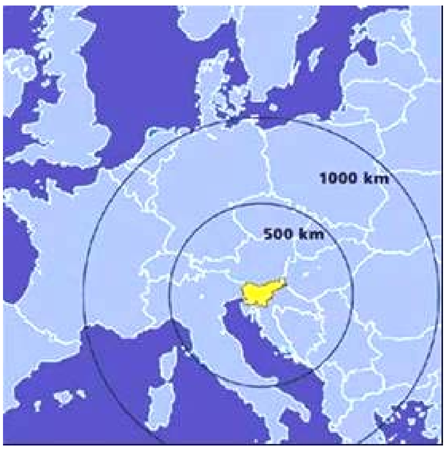
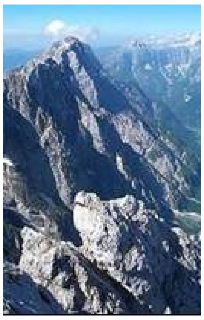



**Fig. X.1. Size and position of Slovenia.**

### *X.1.1 Regions in Slovenia*

Slovenia’s physiogeographical units are the high Alps, Alpine Foreland, Coastal or Sub-Mediterranean region, Dinaric Plateaus of continental Slovenia and the Sub-Pannonian region. Climatically, Slovenia can be divided into the Alpine-Foreland region with high Karst, Intramontane depressions, Sub-Pannonian-Pannonian and Mediterranean belts. Bio-geographical regions are the Coastal, Dinaric, Sub-Dinaric, Sub-Alpine, Alpine and Sub-Pannonian regions (Fig. X.2).

Alpine region

Dinaric region

Mediterranean region

Panonic region

**Fig. X.2. Regions in Slovenia.**

### *X.1.2 Natural characteristics*

To consider natural characteristics, there is a need to emphasise the following four issues. First, Slovenia has a high relief (only 10% of Slovenia is lowlands and together with valleys and basins only 18%). In these areas rivers, arable land, main urban areas, economy and traffic infrastructure are concentrated, and represent the heaviest burdens and highest pressures on nature. Most of the landscape is hilly and mountainous; there are even areas with very high mountains. Second, Slovenia is a mosaic of at least 50 different kinds of rock types and several hundreds soil systematic units derived from around 60 soil types. This, in combination with different climatic belts, caused the development of various ecosystems and biotopes. Slovenia is rich in water sources, mainly groundwater and springs which is an important source of drinking water. The river network is very dense with an average of 1.4 km/km$^2$ and in the aquifers there are huge amounts of groundwater.

### *X.1.3 Land use*

In Slovenia, 42.6% of land is agricultural, but only 14.6% is arable land. There is only 1246 m$^2$ of arable land per inhabitant, which is not enough for self-reliance, especially at the present state of technology. More than 50% of Slovenia is covered by forest; the rest is agricultural land, bare rocks and protected areas. The message is clear: every piece of arable land must be preserved, because lost fertile soil cannot be replaced through amelioration of soils with less favourable properties.

### *X.1.4 Major soil groups in Slovenia*

The main soil forming factors are parent material, climate, topography, the influence of living organisms (including the humans) and time. Major soil groups in Slovenia are shallow Leptosols (Lithic, Rendzik, Eutric, Dystric) on high mountains (Alps), Chromic Cambisols on south – west (karstic area) with special form of *Terra rossa* (Rodik Cambisol) on Kras, Chromic Cambisol often pass to Luvisol due to high precipitations, several types of Eutric Cambisols on flysch, marl and basic rocks, Dystrict Cambisols on siliceous rocks and outwash deposits, Fluvisols on alluvial plains and river terraces, Gleysols and Stagnosols on clay and silt sediments (Fig. X.3).

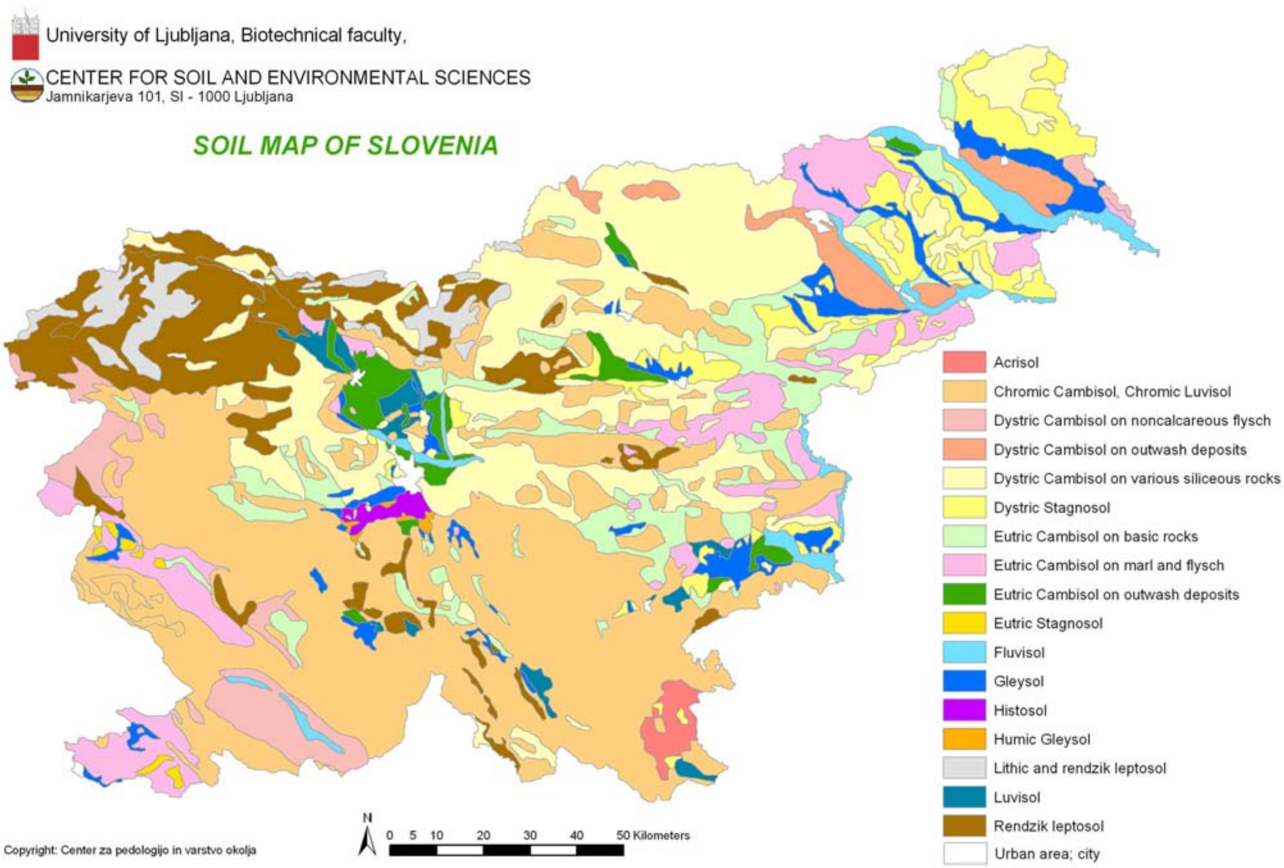



**Fig. X.3. Major soil groups in Slovenia.**

## X.2 Soil legislation in Slovenia

On a new constitutional basis, Parliament passed the Environmental Protection Act (Official Journal of the Republic of Slovenia, No. 41/04) The Act contains general provisions and basic methods of protecting the environment and exploiting natural resources. On the basis of the Environmental Protection Act, new legislation regarding soil protection has been adopted in Slovenia recently:

- Article No. 96. of Environmental Protection Act – monitoring of the State of the Environment (Official Journal of the Republic of Slovenia, No. 32/93, 41/04).
- National Environmental Action Plan (Official Journal of the Republic of Slovenia, No. 83/99) and Resolution on National Environmental Action Plan 2005-2012 (Official Journal of the Republic of Slovenia, No. 2/06).
- Decree on the limit input concentration values of dangerous substances and fertilisers in soil (Official Journal of the Republic of Slovenia, No. 84/05).
- Decree on the Limit, Warning and Critical Concentration Values of Dangerous Substances in Soil (Official Journal of the Republic of Slovenia, No. 68/96).
- Rules on monitoring of the input of dangerous substances and plant nutrients into the soil (Official Journal of the Republic of Slovenia, No. 55/97).
- Regulation on burdening of the soil with waste input (Official Journal of the Republic of Slovenia, No. 3/03).
- Agricultural land act (Official Journal of the Republic of Slovenia, No. 59/96, 31/98 in 01/99).

### *X.2.1 National Environmental Action Plan (NEAP)*

The National Environmental Action Plan (NEAP) was adopted at governmental level in 1999 and as a Resolution on National Environmental Action Plan in 2006. It sets out the goals, guidelines and strategy for environmental protection and the use of natural resources for the next 10 years, subdivided into two five-year periods. In the field of soil protection, the main goals are to prevent further chemical and physical contamination and to perform remedial actions where necessary and feasible. To realise this goals, detailed action plan for the next five years is established including:

- preparation of legislation concerning soil contamination monitoring (National monitoring programme);
- adoption the Codes of Good Agriculture Practice according the Nitrate Directive;
- the assessment of soil pollution (quality);
- establishing soil information system on State level;
- prevention measures including education and training.

The first five years of the NEAP soil pollution assessment programme shows that out of 2692 predefined sampling sites only 13% was completed. Between 1999 and 2001 sampling and analysis were done at 138 sites; in 2001 minimum criteria was set to include other previous surveys of soil pollution from 1989 to 1995 (209 sites), therefore 347 sites out of 2692 (12.8%) were accomplishment according of the first five years of NEAP program. Firstly, areas with more environmental problems were selected for soil pollution assessment (Celje, Zasavje, Jesenice, which are urban, industrial, cultural areas). Because of that, preliminary evaluation of soil quality status for Slovenia was not correct (ratio between contaminated and investigated sites) Slovenia needs to fulfil assessment through/all over the country. In order to finish the assessment as soon as possible, a grid of low density of sampling sites was proposed with sampling priority for non-forestland. The basic 4 km grid for the land below 600 m (non-forestland; 490 sites) and 8 km grid of low density for land above 600 m (179 sites) has been set, which means 669 sites instead of 2692 (1/4 of the 1999 program). In 2004 and 2005 71 sites were finished, which means, there was 240 sites out of 669 finished by the July 2006 of the new ReNEAP (35.4%).

### *X.2.2 Decree on the Limit, Warning and Critical Concentration Values of Dangerous Substances in Soil*

To set up maximum allowed values of dangerous substances in soil, the Decree on the Limit, Warning and Critical Concentration Values of Dangerous Substances in Soil was adopted in 1996 (Official Journal of the Republic of Slovenia, No. 68/96). The decree defines the soil as a surface part of the lithosphere, which consists of mineral and organic substances, water, air and organisms. Concentrations of seven classes of pollutants were determined: heavy metals, inorganic pollutants, aromatic compounds, polycyclic hydrocarbons, chlorinated organic, pesticides and others. This is particularly important in those soils, used to produce foodstuffs. Values below the maximum allowed represent the uncontaminated soils and values over critical concentrations means that a clean-up is necessary. Values over warning allowed values indicate that further investigation is required (Table X.1).

### *X.2.3 Decree on the limit input concentration values of dangerous substances and fertilisers in soil*

The purpose of the decree is to decrease and to prevent water pollution, caused by input of nitrates from agricultural sources and to regulate the usage of sewage sludge, compost or silt/sludge in the way to prevent harmful effects on soil, plants, animals and humans and stimulate the correct usage.

**Table X.1. Limit values, warning values and critical values of dangerous substances.**

| *dangerous substance* | *limit value (mg/kg dry soil)* | *warning value (mg/kg dry soil)* | *critical value (mg/kg dry soil)* |
|---|---|---|---|
| 1. Metals extracted by aqua regia (except Cr6+) | | | |
| cadmium and its compounds, expressed as Cd | 1 | 2 | 12 |
| copper and its compounds, expressed as Cu | 60 | 100 | 300 |
| nickel and its compounds, expressed as Ni | 50 | 70 | 210 |
| lead and its compounds, expressed as Pb | 85 | 100 | 530 |
| zinc and its compounds, expressed as Zn | 200 | 300 | 720 |
| total chromium Cr | 100 | 150 | 380 |
| six valent chromium Cr6+ | | | 25 |
| mercury and its compounds, expressed as Hg | 0.8 | 2 | 10 |
| cobalt and its compounds, expressed as Co | 20 | 50 | 240 |
| molybdenum and its compounds, expressed as Mo | 10 | 40 | 200 |
| arsenic and its compounds, expressed as As | 20 | 30 | 55 |
| 2. Other inorganic compounds | | | |
| fluorides (F-, total) | 450 | 825 | 1200 |
| 3. Aromatic compounds | | | |
| volatile phenols | 0.1 | 20 | 40 |
| Benzene | 0.05 | 0.5 | 1 |
| Ethylbenzene | 0.05 | 25 | 50 |
| Toluene | 0.05 | 65 | 130 |
| Xylene | 0.05 | 12.5 | 25 |
| 4. Polycyclic aromatic hydrocarbons (PAHs) | | | |
| total concentration of PAHs (1) | 1 | 20 | 40 |
| 5. Chlorinated hydrocarbons | | | |
| 5a. Polychlorinated biphenyls (PCBs) | | | |
| total concentration of PCBs (2) | 0.2 | 0.6 | 1 |
| 5b. Insecticides based on chlorinated hydrocarbon | | | |
| DDT/DDD/DDE (3) | 0.1 | 2 | 4 |
| drines (4) | 0.1 | 2 | 4 |
| HCH compounds (5) | 0.1 | 2 | 4 |
| 5c. other phytopharmaceuticals | | | |
| Atrazine | 0.01 | 3 | 6 |
| Simazine | 0.01 | 3 | 6 |
| 6. Other compounds | | | |
| **petroleum based hydrocarbons (mineral oils)** | 50 | 2500 | 5000 |

(1) the total concentration of PAHs is the sum of naphthalene, anthracene, phenantrene, fluorantene, benzo(a)anthracene, kryzene, benzo(a)pyrene, benzo(ghi)perylene, benzo(k)fluorantene and indo(1,2,3)pyrene

(2) the total concentration of PCB is the sum of PCB 28, 52, 101, 118, 138, 153 and 180

(3) the total concentration is the sum of DDT, DD. and DDE

(4) the total concentration is the sum of aldrine, dieldrine and endrine

(5) the total concentration is the sum of $\alpha$-HCH, $\beta$-HCH, $\gamma$-HCH and $\delta$-HCH

**Table X.2. Limit values of annual input of dangerous substances.**

| **Dangerous substance** | **Limit value of annual input (kg/ha)** |
|---|---|
| cadmium and its compounds, expressed as Cd | 0.025 |
| copper and its compounds, expressed as Cu | 3 |
| nickel and its compounds, expressed as Ni | 0.5 |
| lead and its compounds, expressed as Pb | 2.5 |
| zinc and its compounds, expressed as Zn | 10 |
| mercury and its compounds, expressed as Hg | 0.025 |
| total chromium | 2.5 |
| six valent chromium Cr6+ | 0.25 |

# X.3 Procedure of soil pollution assessment

## *X.3.1 Institutions involved*

Several institutions are involved in soil pollution assessment. Coordination of this program is responsibility of Environmental Agency of the Republic of Slovenia (EARS), the executers are laboratories – institutions that have to have accreditation in order to perform research:

- University of Ljubljana, Biotechnical Faculty, Centre for Soil and Environmental Science (CSES),
- Institute of Public Health, Institute of Environmental Protection, Maribor,
- ERICo (Environmental Research & Industrial Co-operation Institute )Velenje,
- National Institute of Chemistry Slovenia, Ljubljana,
- Agricultural Institute of Slovenia,
- Institute of Public Health Novo Mesto.

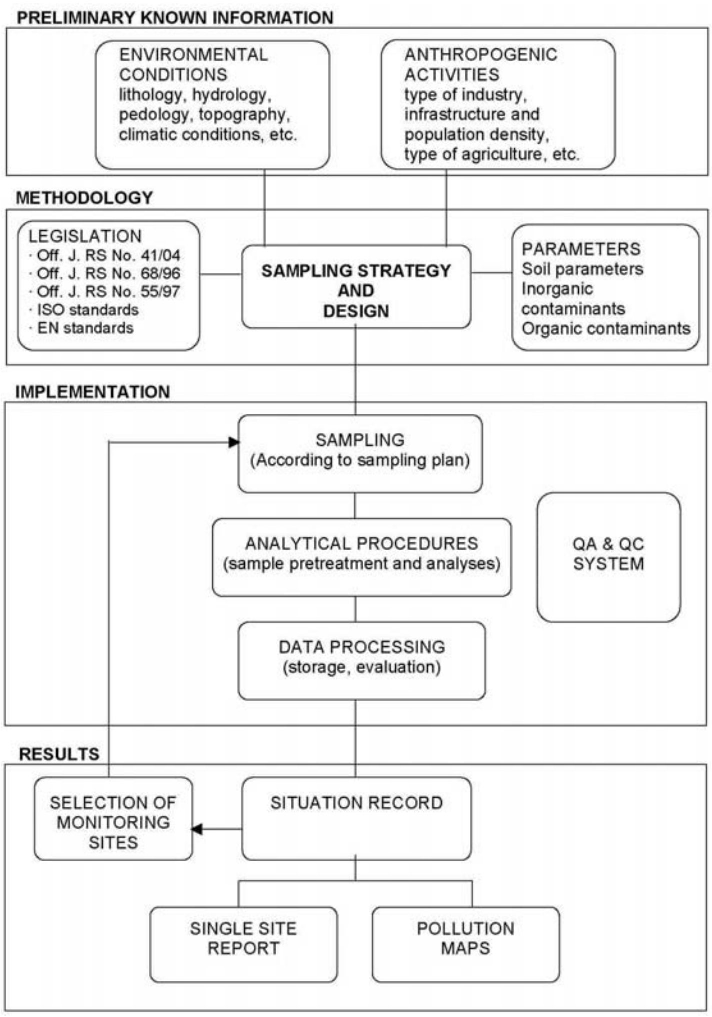



**Fig. X.4. Scheme of soil quality/monitoring system.**

## *X.3.2 Research of Soil Pollution Assessment in Slovenia*

Soil pollution assessment is based on a systematic sampling design with a network of sampling sites with 8 km resolution in general and 4 km resolution on non forest land below 600 m above sea level. A dense grid (2 km resolution) was used in previous years (1989 – 1995) and should be used for vulnerable areas or for regions where pollution is expected. Sampling strategy and design of soil pollution assessment program assure:

- representativity and objectivity of sampling;
- repeatability of sampling procedure;
- appropriate transport and storage of samples;
- repeatability of laboratory procedures.

All details are prescribed in a **sampling program** where preliminary information of investigated areas are taken into account (geology, hydrology, pedology, topography, climatic conditions, possible emission sources, etc). Parameters to be analyzed include: basic soil parameters (consistence, structure, texture, pH, content of organic matter, macronutrients, CEC), organic substances (55 substances including PAHs, PCBs, active compounds of pesticides, and other) and inorganic substances (14 metals or metalloids and fluorides).

**Table X.3. Sampling programme of soil pollution assessment/monitoring in Slovenia.**

| *TASK* | *DEFFINITON / EXPLANATION* |
|---|---|
| sampling pattern | regular grid with 8, 4, 2 or 1 km resolution |
| sampling type | Systematic |
| sampling time | September – November: code for sampling is MMYY |
| sampling depth | tilled ground: D = 0 – 20 cm, C = 20 – 30 cm; |
| | grassland and forest: A = 0 – 5 cm, B = 5 – 20 cm, C = 20 – 30 cm; |
| | in both cases sub samples (increments) are taken from prevalent soil horizon |
| sampling procedure | collecting of 30 increments from 6 soil pits in radius of 50 – 100 m on same land use type for one sampling soil layer |
| sampling equipment | maps, GPS, measure band, spade, buckets, PE bags, stainless trowels, sampling labels, report forms, cooling bags |
| sample labelling | sampling code consists from serial number/time/soil layer: example 06375/1099/A |
| sample archive | after homogenization wet and dry (<2 mm) archive is formed |
| report of sampling | clearly filled up a site record form |

### *X.3.3 Evaluation and presentation of soil pollution data*

The evaluation of soil pollution depends on the concentration of potentially toxic substances and is based on a **three level system** according to **limit**, **warning** and **critical** value of Slovenian legislation (Official Journal, 1996). A simple ‘traffic lights’ colour scheme is used for the presentation of data in both cases as a **single soil sampling site report** or for **soil pollution maps.** The standardised output format for one investigated site contains four pages. Location and geographical position in scale 1:25,000, soil type, parent material, land use, soil pollution sources, sampling personnel data, etc., are presented on first page. The data on soil morphology (soil structure, texture, consistence, colour, etc.) of sampled layers and the data of measured physical and chemical properties are tabulated on second page. The colour coded concentrations of inorganic pollutants are shown on third page, and the colour coded concentrations of organic pollutants on page four.

**Table X.4. General action plan for contaminated soils.**

| *DEGREE OF POLLUTION* | *ENVIRONMENTAL IMPACT* | *ACTION* | *LAND USE* | *FOOD AND FODDER PRODUCTION AND DRINKING WATER* |
|---|---|---|---|---|
| *under detection limit* | no impact | Prevention | without limitations | without limitations |
| *under limit value* | no impact | Prevention | without limitations | without limitations |
| *under warning value* | hazards not to be expected | strict prevention and soil pollution control | conditionally all type of land use, not recommended for gardens | not recommended for production of leafy and root vegetables, periodical control of plants and water |
| *under critical value* | hazards possible | further soil pollution research and simple sanitation steps (land use imitations) | conditionally all type of land use, but not allowed for direct food production | not recommended for vegetable production and limitations for other agricultural plants, regular and frequent control of plants and drinking water |
| *above critical value* | hazards certain | remediation and/or recultivation process | non agricultural land use | not allowed for food and fodder production, soil surface must be overgrown, regular control of drinking water |

Soil pollution maps can be prepared for each metal and soil layers (depth) in optional scale depending on the size of the area. Soil pollution data are presented as points or as interpolated contour plots if a density of sampling procedure and number of sampling sites are appropriate. Despite the detailed monitoring legislation, no guidelines are given on the treatment of polluted soils except for the critically contaminated surfaces. General action plan for contaminated soil according to the pollution levels is proposed in Table X.4.

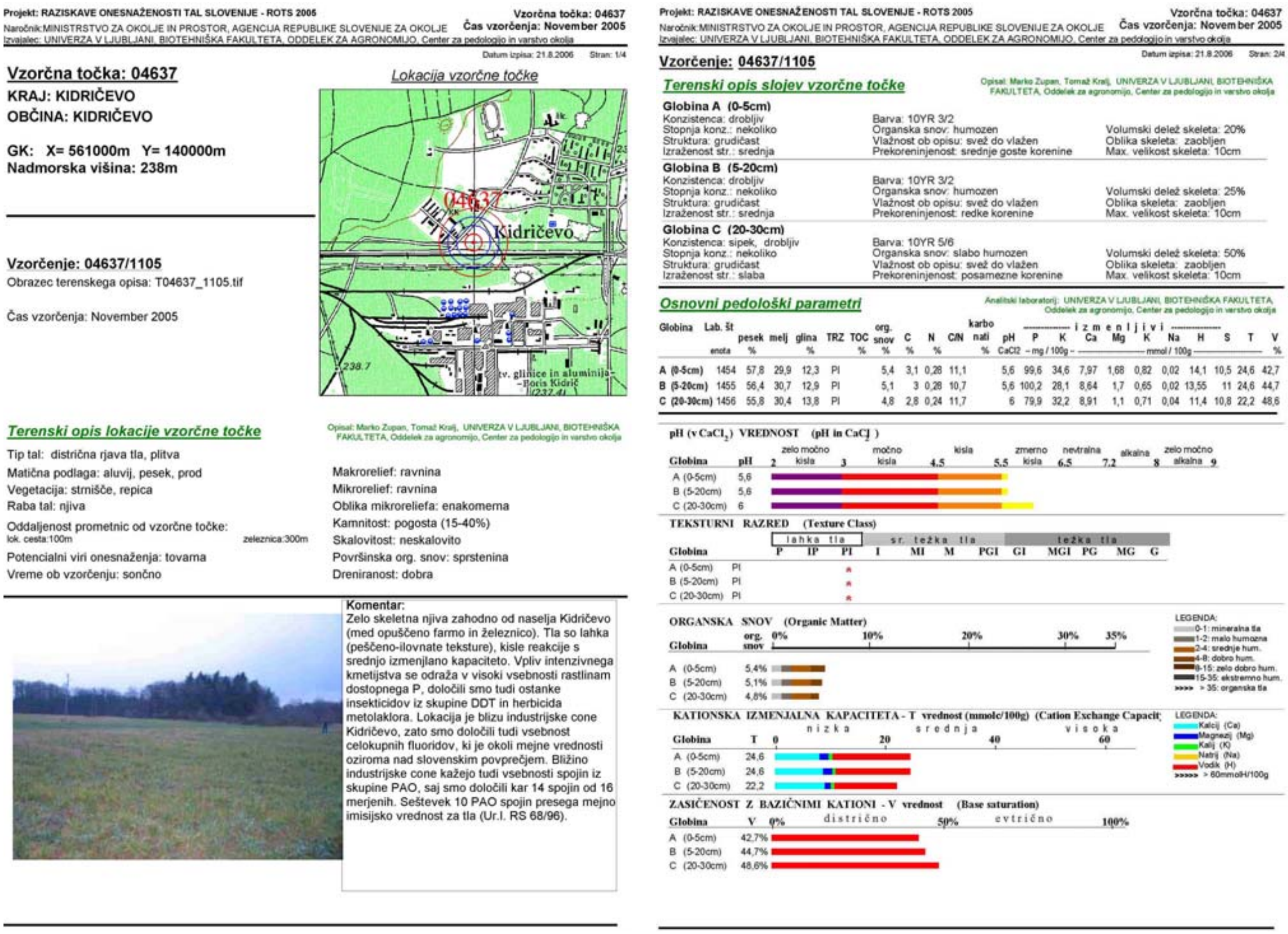



**Fig. X.5. Standardized report page 1 and 2.**

On the a third and fourth page, inorganic and organic substances are presented in tables and in a graphic scheme. Again a three-color traffic-light bar is used. It must simple and understandable. Red is "*too much*", green is "*OK*" and yellow is assigned to intermediate values. It's very easy to find what the result is and what it means. The data can be presented also as thematic maps, where sites are colour based on the concentration the same way – from green over yellow to red or even purple for highly polluted.

## X.4 Data availability

Basic data on soils are produced, developed and maintain at the Centre for Soil and Environmental Science (CSES), University of Ljubljana. CSES was authorised by the Ministry for Agriculture, Food and Forestry of Slovenia to conduct soil mapping and establish Digital Soil Map of Slovenia in scale 1:25,000, and by Ministry of the Environment and Spatial Planning to provide Soil Quality assessment & soil monitoring networks. CSES organized soil data into Soil Information System (SIS) with spatial and attribute (measured or estimated) information. The basic goal of SIS is to unite various geographically defined soil data and soil related data into comprehensive and accessible information system using GIS tools and methods. The financing of SIS is not jet supported by the state and data availability is not accessible in full range (Lobnik et al., 2003).

Data of soil related projects financed by Environmental Agency of Republic of Slovenia (EARS) will be integrated in Oracle database at the EARS. A database on soils is under development and will be related to water and air data in the near future. SDE database is under development and will link all thematic layers – air, water, soil in a GIS. Reports are available for the public on the Internet; other data (results) are available at Environmental Agency of the Republic of Slovenia on request. Soil data is not part of a reporting to the EEA. Reporting to the EEA is not obligatory and Slovenia does not report, since the requested data is referring to contaminated sites. This information is not yet available in Slovenia, since there is no inventory on contaminated sites, yet.

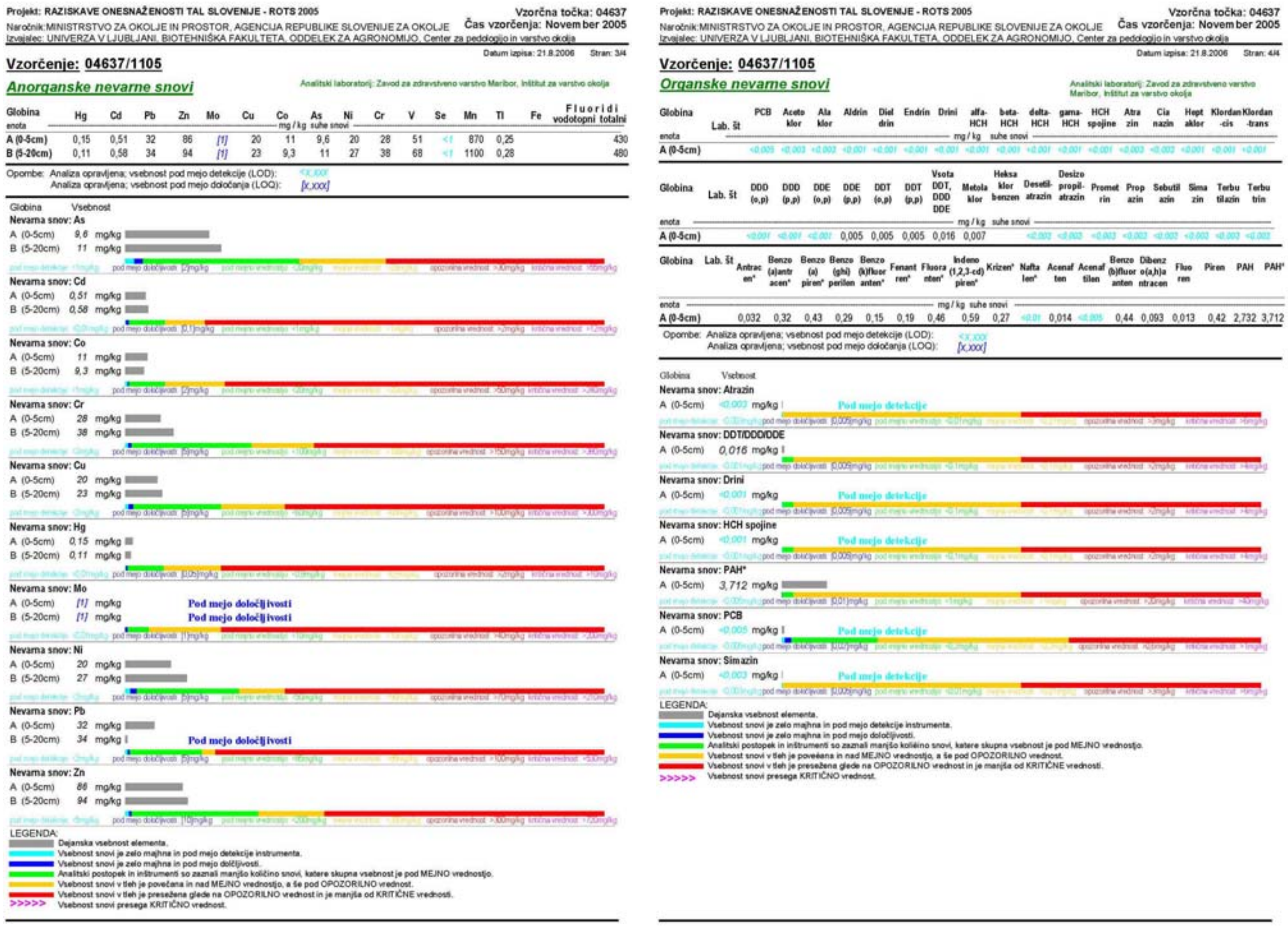



**Fig. X.6. Standardized report page 3 and 4.**

## X.5 Future actions

### *X.5.1 Expectations and suggestions*

At the EU level, soil protection legislation is poorly developed in comparison to that relating to other media, such as air and water. It should receive the same attention as air and water. Harmonised soil monitoring system needs to be established in order to record the state of soil pollution at national and EU level. Legislation of EU is in process, but not yet harmonized on national level of all member states (see the soil monitoring working group report, Van-Camp et al, 2004).

### *X.5.2 What should be done?*

- comparison of existing proposal for Slovenia (ROTS, 2000) which should be harmonized regarding the EU guideline (harmonization of reference methods for parameters, equipment and holders of activity),
- to compile and implement rules for soil contamination monitoring,
- elaboration of a framework programme of sampling regarding ReNEAP objectives,
- monitoring establishment and defining operative method and form of reporting for state and EU purposes,
- soil information system and its inclusion in others (GIS) information systems,
- proposal of remediation measures for most endangered areas,
- survey of remediation actions.

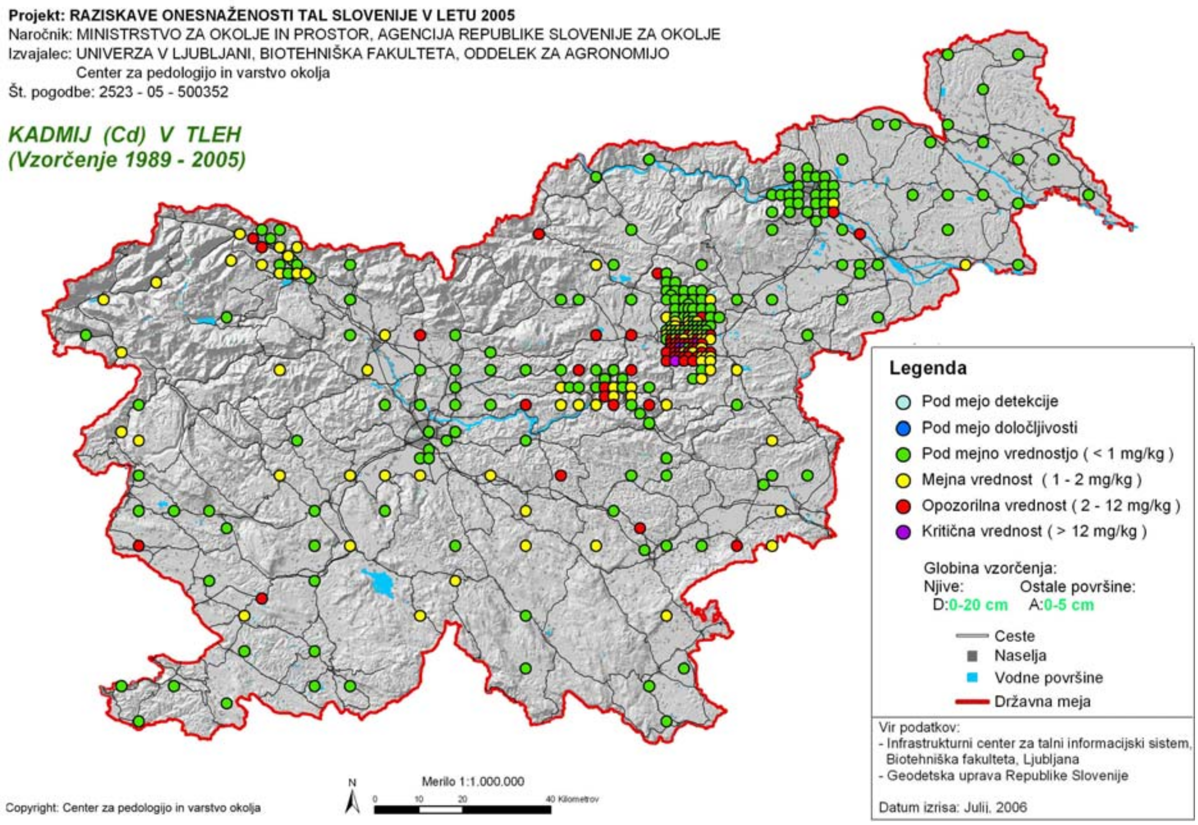



**Fig. X.7. Thematic map, example of Cadmium.**

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# XI. Danube basin Soil database

Beata Houšková

Land Management and Natural Hazards Unit
European Commission, Directorate General JRC, Institute for Environment and Sustainability, TP 280, Via E. Fermi 1, I-21020 Ispra (VA), Italy
Tel.: + 39 0332 786329; Fax: + 39 0332 786394
beata.houskova@jrc.it

**Summary**

*The Danube basin Soil database is build up for purposes of collecting data concerned with soils from countries of Danube river basin. These data serve as a part of a distributed water-balance, flood simulation and flood inundation model LISFLOOD. The model is used in the European Flood Alert System (EFAS) to provide one to ten days real-time forecast system. The Danube basin Soil database is also part of The Georeferenced Soil database of Europe included into European Soil Information System (EUSIS) and European Soil Data Centre (ESDAC). Both of these JRC tasks: floods forecast and data centre, need cooperation with relevant countries. The Database follows the rules specified in the Georeferenced Soil Database for Europe, Manual of Procedures Version 1.1 (EC – JRC, ESB, 2003).*

## XI.1 1 Introduction

The climate change starts to be real and actual phenomenon in present days. Usually, annual sum of temperatures and precipitation does not change significantly but there are significant changes in their redistributions during the year. The change is shifted to extreme weather conditions during the summers which are characterised with increasing intensity and appearance of heavy rains alternating with dry and very hot periods. The soils during dry and hot periods change their properties and react in different way on excess of water from rains as if they are not dry. Infiltration rates for water are decreased significantly, especially in case of bare soils. Taking into consideration the fact that heavy rains are typical for second halve of summer when harvest is coming to finish or already finished the probability that soil is without plant cover is very high. Decreased infiltration ability of agricultural soils together with decreased infiltration ability of the environment as a whole due to covering soils with asphalt and concrete by building new roads systems and settlements invokes floodings. Nowadays, floodings are more frequent and can be more intensive as they have been several years ago. All these facts come into needs of prediction of such phenomena. High amounts of emissions cause so-called greenhouse effect. The most harmful greenhouse gases according to amount and influence on environment are: CO2, CH4, N2O, NOx, CO, SO2 and volatile organic compounds. The biggest producer of CO2 and SO2 is energy producing industry. Agriculture is the biggest producer of methane and N2O. It does not share on the production of the other emissions.

Direct risk from emissions is given to the forest because it is main and very often only one absorbent of them. In last 100 years total air temperature increased in average from 0.3 °C to 0.7 °C. Partly it is due to natural changes (natural climate turns, changes in Earth axes….) but there is also coherence with human activities. Climate change does not know borders and connected with floodings on one and droughts on the other side constitute problem for European countries. This problem then must be solved not only on national but as well as European level. Example how to deal with this phenomenon is the European Flood Alert System (EFAS). The role of EFAS is to provide one to ten days real-time forecast system. Flood risk assessment models based on the actual data from different parts of environmental information sources serve to these purposes. Soil is active part of environment and soil data should be included is floodings predictive models otherwise the results coming out from these models can be quite far from the reality.

For these purposes the Soil Information System of the Danube River Basin (SIS-Danube) was created and still has to be filled up with soil and soil related data from missing countries of Danube river basin area. Such soil information system is an integral part of the Flood Risk Assessment Project, which is executed among the institutional JRC tasks. It is also an integral part of the Georeferenced Soil Database for Europe at the scale 1:250,000, one of the main elements of the **European Soil Information System** (EUSIS) and **European Soil Data Centre** (ESDAC). Construction of the database is based on several materials: The Georeferenced Soil Database for Europe, Manual of Procedures, Version 1.1. (ESB, 2003); LISFLOOD, a distributed water-balance, flood simulation and flood inundation model, Version 1.0. (Ad De Roo, Jutta Thielen, Ben Gouweleew. EC/JRC, 2002) and the procedures and experiences developed in the pilot project creating the soil digital database for the

Odra basin at the scale 1:250,000 (final report, Warsaw, 2001). The database structure is based on soil and landscape data in three levels of information: soil region, soilscape and soil body. Soil body together with soil horizons characteristics is the most detailed soil information in the database structure. JRC uses for floodings prediction the LISFLOOD model, which is based on the input and output data.

Input data include: CORINE land cover, Soil Database Parameters, Flow rates, Meteorological Data, Geological Data and Digital Elevation Model. Output data cover annual results about daily discharge (Water balance module), daily-weekly results and hourly discharge (Flood simulation module), hourly-daily results and flood extent (Floodplain inundation Module). Soil database parameters needed for the model comprise general information as dominant soil in soilscape and number of soil region. Information about physiography of studied area is represented via major landform, regional slope, hypsometry degree of dissection, ground water table, presence of permanent water logging, minimum and maximum altitude, relief intensity, slope length and dominant slope and surface form. Parent material includes information about its kind and is represented via parent material surface level, depth to parent material change and parent material subsurface level. Basic soil properties needed for the model include information about textural composition of topsoil and subsoil, bulk density and organic matter content. Pedotransfer functions coming out from **HYPRES**, acronym for the European project: Hydraulic properties of European Soils, are used to calculate from basic soil data the saturated hydraulic conductivity, total porosity or full saturation of soils. The Soil Information System of the Danube river basin can serve as an example of the multifunctional use of soil databases.

Danube basin Soil database represents one of the tasks of JRC to build up databases for all European basins. These databases will be used in alert system for flooding predictions. Weather driven hazards have increasing importance in European environment and are coming together with climate changes. Pan-European Flood alert System (EFAS) serves for flooding prediction and warning up. It exploits LISFLOOD model based on modelling environment as a whole. Besides soil data there is information concerning land use change, urban expansion, climate, hydrological situation. The aim is to build Sustainable Urban Development and Integrate management of extreme events, including concepts and methods for integrated territorial management at European Union, river basin and regional level.

### *XI.1.1 2 Structure of LISFLOOD model*

**LISFLOOD model** was created on JRC in Land management unit for the **European Flood Alert System** (EFAS) purposes (Fig. XI.1). It is a distributed rainfall-runoff model focused on catchment areas and evaluating the origin and causes of flooding taking into account also land use and soil characteristics like soil moisture content, soil texture and organic matter content. Main principle of LISFLOOD model is to simulate runoff and flooding in large river basins as a consequence of extreme rainfall. In the future all European river basins should be investigated from the risk of possible floodings and the way how this flooding will develop in certain river basin.

Among soil characteristics the LISFLOOD model uses hydrological data like discharge and flow, daily precipitation and the others. From this point of view it is not easy to fill sufficient amount of actual data into such type of model. This is reason why JRC is collecting the data and offering to the EU countries the floodings early warnings. Due to its “cascade” structure with aspect of time the user can decide the time step:

- LISFLOOD – WB: a water balance model (daily step interval
- LISFLOOD –FS: a flood simulation model (hourly step interval)
- LISFLOOD – FP: a flood plain inundation model (second time interval).

Model simulated processes are precipitation, interception, snowmelt, evapo-transpiration, infiltration, percolation, groundwater flow, lateral flow and surface runoff. For these purposes model needs a lot of input data of rainfall and temperature time series with different scale of actuality. The set of input data is listed below:

- CORINE land cover
- Soil database parameters (soil texture and depth)
- Flow rates (the river channel network)
- Meteorological data (precipitation, temperature, wind, humidity)
- Geological data
- Digital Elevation model

On the other hand the output data from this set are obtained by different modules. Annual results and daily discharge are used in Water balance module, daily and weekly results as well as hourly discharge are in Flood simulation module and hourly – daily results and flood extent comes into Floodplain inundation module.

The basic schema of LISFLOOD model deals with precipitation and different kinds of precipitation (rainfall, snowmelt), different types of precipitation redistribution, like infiltration (depends of amount, intensity and duration of rainfall), overland flow and channel flow. Model takes into account also groundwater presence and depth of occurrence.

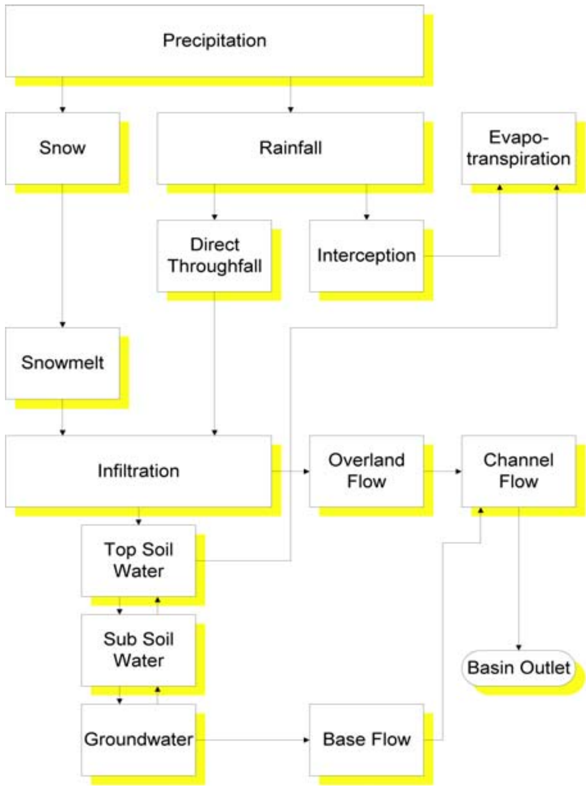


**Fig. XI.1. The structure of LISFLOOD model. After Ad de Roo *et.al.* (EC/JRC 2002).**

## XI.2 3 Structure of Georeferenced Soil database

Structure and content of Danube basin Soil database is built up according to the rules coming out from the Manual of Procedures, Ver. 1.1 (ESB, IES/JRC, EUR 18092 EN). General schema of the database is in Fig. XI.2. The main purposes of the manual are:

- To define the structure of the database;
- To describe the methods of georeferenced the data;
- To outline suggested procedures for regional mapping and sampling programmes;
- To prescribe a format of data storage;
- To ensure inter-regional and inter-country harmonisation of data acquisition, processing and interpretation;
- To create the user-friendly soil database.

From the schema is evident that geometrical part of database is represented by soil regions and soil scapes.

### *XI.2.1 Soil region*

Soil region is defined by similar soil forming conditions. Soil regions are characterised by dominant soil type, dominant parent material, climatic data, altitudes and major landforms. They represent the largest areas and provide for users basic soil related information. Soil regions are represented on the map with 1:5M scale. Each soil region is characterised by parent material, dominant parent material, climatic data and altitudes and major landform.

### *XI.2.2 Soil scape*

Soil scape is association of soil bodies which have former or present relationships and can be represented at 1:250,000 scale. The main diagnostic criterion in distinguishing between soil scapes is relief. The most important morphological attitudes are slope, slope length, altitude, and curvature. Information on soil scape level is the basis for geometric part of the database.

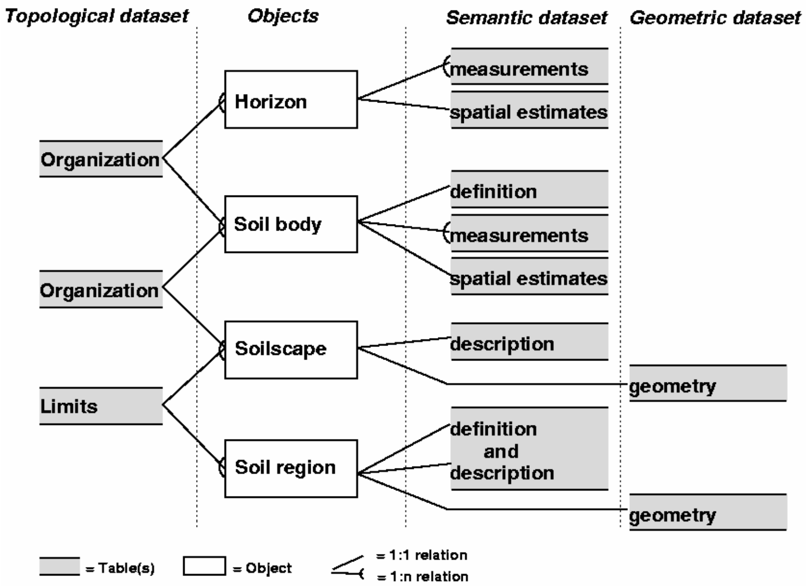


**Fig. XI.2. General structure of Georeferenced Soil Database of Europe, 1:250,000 (as actual till end of 2006).**

### *XI.2.3 Soil body*

A soil body is a portion of soil cover with diagnostic characteristics resulting from similar processes of soil genesis. Morphological and analytical attributes of the main horizons are part of soil body description.

## XI.3 Structure of Danube basin soil database

For purposes of building up the coherent soil information system which can be used in the process of floodings modelling, the Danube soil database has the information on soil body level. This type of information was asked from contributors. Database consists from the set of georeferenced point data (with *X*, *Y* coordinates in decimal degrees). There are point data (with *X*, *Y* coordinates) and information is delivered on three levels:

- Soil body definition table;
- Soil body measuring table;
- Horizon measurement table.

In Table XI.1, 2 and 3 are parameters of the respective levels of information, type of information (character or number), remark if the field is mandatory or compulsory, example and explanation. In the case of the type of soil classification it is not important to use the latest versions but to mention the year when the classification was issued, e.g. WRB (1994), WRB (1998), WRB (2006) etc.

Number of point data for one contributing country is about 1200 points. The soil data are according to soil horizons in the profile or the information is for topsoil and subsoil. In present time the database comprises data coming from Slovak Republic, Austria, Czech Republic, Romania, Hungary, Bosnia-Herzegovina, Slovenia and Bulgaria. Negotiations started with Croatia, Germany, Serbia and Moldova. In present time there are not yet negotiations with Ukraine.

**Table XI.1. Soil body definition table.**

| Identifier | Type | Mandatory | Example | Description |
|---|---|---|---|---|
| `soil_body (key)` | char 10 | yes | 33.2.SB81 | *Depth to obstacle for roots* |
| `sb_wrb` | char 10 | yes | stn-vr -LV | *WRB-classification* |
| `sb_mat` | char 3 | yes | 900 | *Parent material* |
| `sb_obst` | char 1 | yes | 1 | *Code soil body (SB821) within soil region (33.2)* |

**Table XI.2. Soil body measurement table.**

| Identifier | Type | Mandatory | Example | Description |
|---|---|---|---|---|
| `soil_body (key)` | char 10 | yes | 33.2.SB821 | *code soil body (SB821) within soil region (33.2)* |
| `sbsm_X` | num 5 | yes | 12.10 | *X-coordinate representative soil profile (eastern latitude)* |
| `sbsm_Y` | num 4 | yes | 35.20 | *Y-coordinate representative soil profile (longitude)* |
| `sbsm_alt` | num 4 | yes | 812 | *Surface altitude (meter a.s.l.)* |
| `sbsm_depw` | num 3 | yes | 20 | *average depth to water table (dm)* |

**Table XI.3. Soil horizon measurement table.**

| Identifier | Type | Mandatory | Example | Description |
|---|---|---|---|---|
| `Profile_id` | Char max 20 | yes | | *This ID will be identical with original one used in each country and unique for data provided* |
| `Profile_sm_alt` | Num 4 | yes | 812 | *Surface altitude (m above s. l., potentially below s. l. (Measurement Unit: meter). Minus (-) sign in case below sea level* |
| `Profile_sm_depw` | Num 3 | yes | -20 | *Average depth to water table. Water table deeper than 2 m. (Measurement Unit: dm)* |
| `Profile_hor_num` | Num | yes | 3 | *Total amount of soil horizons provided per one profile (point) information* |
| `Profile_hor` | Char 3 | yes | 1 ap | *Soil horizon code* |
| `Profile_hm_top` | Num 3 | yes | 0 | *Soil horizon starting depth. (Measurement Unit: cm)* |
| `Profile_hm_bot` | Num 3 | yes | 20 | *Soil horizon ending depth. (Measurement unit: cm)* |
| `Profile_hm_clay` | Num 3 | yes | 20.4 | *Clay content (Measurement unit: %, decimal indicator is dot.)* |
| `Profile_hm_clayQ1` | Char 10 | yes | NLD01_1988 | *Country, laboratory and year of analysis.* |
| `Profile_hm_clayQ2` | Char 1 | yes | m | *Quality estimate of analysis* |
| `Profile_hm_silt` | Num 3 | yes | 40.5 | *Silt content. (Measurement unit: %, decimal indicator is dot.)* |
| `Profile_hm_siltQ1` | Char 10 | yes | NLD01_1988 | *Country, laboratory and year of analysis.* |
| `Profile_hm_siltQ2` | Char 1 | yes | m | *Quality estimate of analysis* |
| `Profile_hm_sand` | Num 3 | yes | 39.1 | *Sand content. (Measurement unit: %, decimal indicator is dot.)* |
| `Profile_hm_sandQ1` | Char 10 | yes | NLD01_1988 | *Country, laboratory and year of analysis.* |
| `Profile_hm_sandQ2` | Char 1 | yes | m | *Quality estimate of analysis* |
| `Profile_hm_stgr` | Char 2 | yes | VF | *Stone, gravel abundance and size* |
| `Profile_hm_stgrQ1` | Char 10 | yes | NLD01_1988 | *Country, laboratory and year of analysis.* |
| `Profile_hm_stgrQ2` | Char 1 | yes | m | *Quality estimate of analysis* |
| `Profile_hm_om` | Num 3 | yes* | 4.5 | *Organic matter content. (Measurement unit: %, decimal indicator is dot.)* |
| `Profile_hm_omQ1` | Char 10 | yes | NLD01_1988 | *Country, laboratory and year of analysis.* |
| `Profile_hm_omQ2` | Char 1 | yes | m | *Quality estimate of analysis* |
| `Profile_hm_hum` | Num 3 | yes* | 7.8 | *Humus content. (Measurement unit: %, decimal indicator is dot.)* |
| `Profile_hm_humQ1` | Char 10 | yes | NLD01_1988 | *Country, laboratory and year of analysis.* |
| `Profile_hm_humQ2` | Char 1 | yes | m | *Quality estimate of analysis* |

*If either humus or organic matter information is missing.

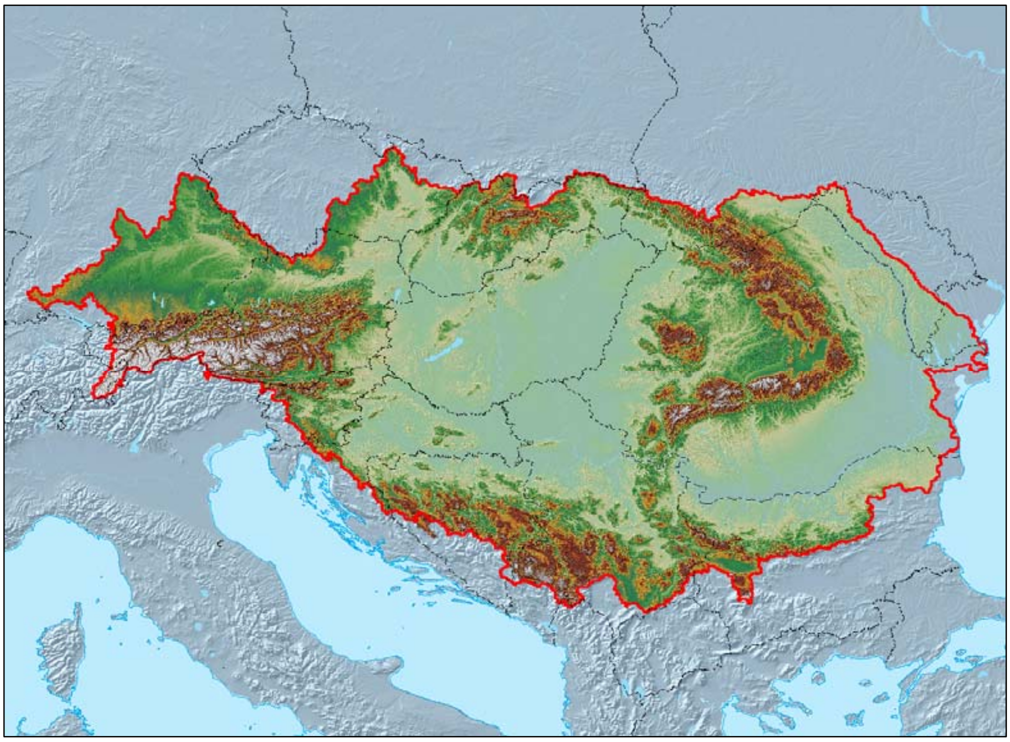

**Fig. XI.3. Area and countries of Danube basin.**

For the map of the Danube basin is used the ETRS89 Lambert Azimuthal Equal Area Coordinate Reference System (ETRS-LAEA) which is a single projected coordinate reference system for all of the Pan-European area. It is based on the ETRS89 geodetic datum and the GRS80 ellipsoid.

## XI.4 Soils in the Danube river basin

Danube basin is the largest basin of Europe. According to the Geographic Information System of the European Commission (GISCO), its area of 817,000 km$^2$, length of the basin is 2857 km and population living there is around 80 millions of people (Fig. XI.3). It is necessary to know possible environmental risks in this huge area, to prevent them or/and to know about them in advance. LISFLOOD prediction model with soil properties as part of is a nice example of European cooperation. In the Danube river basin the heterogenity of soil cover is very high because of different soil forming conditions across this huge area and also because of high heterogenity of many soil properties in general. In the Table XI.4 is the variability coefficient of soil found out at the area of one hectare on the equal soil morphological unit.

**Table XI.4. Variability coefficient of soil.**

| *Coefficient of variability (CV)* | *Soil property, soil composition* |
|---|---|
| Low (CV<15%) | pH, thickness of A horizon, $\Theta_s$, $\rho_d$ |
| Medium (CV=15 up to 35%) | Amount of sand and clay fraction, CEC, $CaCO_3$ (%), $\Theta_W$, $\Theta_{FC}$, depth of $G_r$ horizon |
| High (CV=35 up to 70%) | Humus content, soluble salts content in arid zones, actual soil moisture content, depth and thickness of B horizon, depth of $CaCO_3$ leaching, sorptivity |
| Very high (CV>70%) | $K_s$, $K_{(h)}$ generally, $K_{(h)}$ at the same pressure height or moisture, diffusivity |

*Explanations:
$\Theta$ – soil moisture in % of volume; $\Theta s$ – full saturation; $\Theta_W$ – wilting point; $\Theta_{FC}$ – water content at field capacity
$G_r$ -stagno gleic horizon; $K_s$ – saturated hydraulic conductivity; $K_{(h)}$- unsaturated hydraulic conductivity;

Nevertheless soil heterogeneity is lower on soil morphological subunit level. Genetic group of chernozems has different water regime of subunit level. Calcaric and haplic chernozems with non-percolative water regime differ from Luvi-haplic chernozems with periodically percolative water regime and for salic chernozems evaporative water regime is typical. Due to clay content which may accumulate in soil profile, the soil retention capacity increases. In generall, gleying processes lead to unfavourable water regime and increase soil heterogeneity. All these factors must be taken into account in the process of soil data evaluation and assessment.

For aggregating soil related data into soil groups the morphogenetic principle was used. Morphogenetic pronciple is based on similar soil properties of genetic horizons: morphologic, physical, chemical and biological and on similar or the same soil forming process. Results of this aggregation are 10 main soil groups formed from present data. This amount of soil groups may change together with the new soil data coming into Danube river basin Soil database. In the Table XI.5, main soil groups are illustrated together with soil types belonging to them. The WRB (1994) classification is used.

**Table XI.5. Soil groups according to similar properties from morphological and genetical point of view in Danube basin area.**

| *SOIL GROUP* | *SOIL UNIT (WRB, 1994)* |
|---|---|
| G1 | *Lithic Leptosols*<br>*Rendzi-Lithic Regosols* |
| G2 | *Skeletic, Umbric, Dystric, Mollic, Eutric, Cambi-Dystric, Cambi-Eutric, Rendzic Leptosols;*<br>*Calcaric, Stagni-Calcaric, Chromi-Calcaric Cambisols* |
| G3 | *Haplic, Ca;caric Vertisols;*<br>*Haplic, Areni-Haplic, Verti-Haplic, Luvi-Haplic, Cambi-Haplic, Stagni-Gleyic Chernozems;*<br>*Mollic, Hapli-Gleyic, Verti-Gleyic, Gleyi-Haplic Chernozems, Mollic, Histi-Mollic Gleysols* |
| G4 | *Greyic, Luvic Phaeozems;*<br>*Haplic, Calcic, Albi-Haplic, Stagni-Haplic, Chromic Luvisols, Luvic Arenosols;*<br>*Albic, Albi-Dystric, Albi-Chromic Luvisols, Albi-Luvic Arenosols, Haplic, Stagnic Glossisols* |
| G5 | *Eutric, Dystric, Molli-Eutric, Andic, Chromic Cambisols, Cambic, Haplic, Skeletic Umbrisols;*<br>*Eutric, Pachic, Vitric , Silic, Umbri-Silic Andosols* |
| G6 | *Haplic, Cambic, Umbric, Gleyic, Stagnic, Foli-Haplic, Histi-Haplic podzols* |
| G7 | *Haplic, Fluvic, Arenic, Histi-Mollic, Histi-Umbric, Histic Gleysols;*<br>*Haplic, Leptic, Fibric Histosols* |
| G8 | *Eutric, Dystric, Calcaric, Vertic Fluvisols* |
| G9 | *Haplic, Gleyic, Mollic, Sodic Solonchaks, Salic Fluvisols;*<br>*Haplic, Gleyic, Albi-Haplic Solonetz* |
| G10 | *Urbi-Anthropic Regosols, Anthropo-Skeletic Leptosols* |

For soil catenas the typical altitudes of occurence are characteristic. This principle can be used also in the process of transforming the point soil information into area information (grids or polygons). In Table XI.6 are these typical altitudes of the occurence of European soils. The altitude influences also soil use and plant cover.

General problems in the process of data harmonisation in the Danube river basin soil database are connected with errors in the sum of textural categories, harmonisation of different soil classification systems and conversion tables from national into WRB system, coordinates of points in another country, mixing of different WRB issues (e.g. 94, 98) and anomalies of some soil properties, e.g. hot spots of high organic matter or humus content and how to deal with them. All these problems can be eliminated and it is true that this is an huge database comprising high level of soil related information. The Danube river basin Soil database is nice example of the colaboration between countries on European level.

**Table XI.6. Typical altitudes for Individual Soil Units Occurence, land use and land cover in Danube Basin.**

| *Soil Unit (WRB, 1994)* | *Altitude (M A.S.L.)* | *Soil Use Plant Cover* |
|---|---|---|
| *Lithic Leptosols, Rendzi-Lithic Leptosols* | 1800–2665 | Alpine meadows |
| *Eutric, Dystric, Calcaric, Skeli-Eutric, Clayi-Eurtic Regosols, Skeletic Leptosols, Haplic, Calcaric Arenosols* | 130–600 | Arable land, orchards, forest |
| *Skelic, Umbric, Dystric, Mollic, Eutric, Cambi-Dystric, Cambi-Eutric Leptosols* | 1300–1800 | Alpine meadows |
| *Rendzic, Foli-Rendzic, Skeli-Rendzic, Chromi-Rendzic Leptosols* | 200–2000 | Forest, alpine meadows, partly arable land |
| *Calcaric, Stagni-Calcaric, Chromi-Calcaric Cambisols* | 200–800 | Arable land, orchards, forest |
| *Haplic, Calcic, Calcaric Vertisols* | till 200 | Arable land |
| *Haplic, Areni-Haplic, Verti-Haplic, Luvi-Haplic, Cambi-Haplic, Stagni-Gleyic Chernozems* | 110–300 | Arable land |
| *Mollic Fluvisols, Hapli-Gleyic, Verti-Gleyic, Gleyi-Haplic Chernozems, Mollic, Histi-Mollic Gleysols* | 95–200 | Arable land |
| *Greyic, Luvic Phaeozems* | 150–350 | Arable land |
| *Haplic, Calcic, Albi-Haplic, Stagni-Haplic, Chromic Luvisols, Luvic Arenosols* | 150–480 | Arable land |
| *Albic, Albi-Dystric, Albi-Chromic Luvisols, Albi-Luvic Arenosols, Haplic, Stagnic Glossisols* | 150–600 | Arable land, orchards, greenwood (oak-trees) |
| *Eutric, Skeli-Eutric, Verti-Eutric, Andic, Luvi-Eutric, Eutri-Chromic Cambisols* | 145–800 | Greenwood, orchards, arable land |
| *Dystric, Dystri-chromic Cambisols* | (200) 600–1400 | coniferous wood, pasture |
| *Eutric Andosols* | 500–800 | Greenwood, arable land |
| *Vitric, Silic (Umbri-Silic) Andosols* | 800–1500 | Pasture |
| *Haplic, Humic, Cambic, Umbric Podzols* | (800) 1400–2000; also about 200 | Alpine meadows, scrubs, coniferous wood |
| *Dystric, Eutric Planosols, Luvic, Albic, Haplic, Gleyic, Histi-Haplic Stagnosols* | 200–1000 | Greenwood, permanent grassland, arable land |
| *Haplic, Fluvic, Arenic, Histi-Mollic, Histi-Umbric Gleysols* | Usually from 95 m till stream's springs | Mainly permanent grassland, partly arable land |
| *Haplic, Leptic, Fibric Histosols, Histic Gleysols* | Lowlands-uplands | Peat exploitation |
| *Eutric, Dystric, Calcaric Fluvisols* | Alluvial parts of streams | Arable land, permanent grasslands, meadow forrest |
| *Haplic, Gleyic, Mollic, Sodic Solonchaks* | 100–130 | Mainly grassland |
| *Haplic, Gleyic, Albi-Haplic Solonetz* | 100–130 | Mainly grassland |
| *Albic, Albi-Dystric, Albi-Chromic Luvisols, Albi-Luvic Arenosols, Haplic, Stagnic Glossisols* | 150–600 | Arable land, orchards, greenwood (oak-trees) |
| *Eutric, Skeli-Eutric, Verti-Eutric, Andic, Luvi-Eutric, Eutri-Chromic Cambisols* | 145–800 | Greenwood, orchards, arable land, |
| *Dystric, Dystri-chromic Cambisols* | (200) 600–1400 | coniferous wood, pasture |
| *Eutric Andosols* | 500–800 | Greenwood, arable land |
| *Vitric, Silic (Umbri-Silic) Andosols* | 800–1500 | Pasture |
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| *Haplic, Leptic, Fibric Histosols, Histic Gleysols* | Lowlands-uplands | Peat exploitation |
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| *Haplic, Gleyic, Mollic, Sodic Solonchaks* | 100–130 | Mainly grassland |
| *Haplic, Gleyic, Albi-Haplic Solonetz* | 100–130 | Mainly grassland |

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# XII. SPADE2: The soil profile analytical database for Europe

Jacqueline A. Hannam, John M. Hollis and Robert J.A. Jones

National Soil Resources Institute, Department of Natural Resources, School of Applied Sciences, Cranfield University, Cranfield, MK43 0AL, United Kingdom.
Tel.: + 44 1234 750111; Fax: + 44 1234 752971
j.a.hannam@cranfield.ac.uk; hollises@dsl.pipex.com; r.jones@cranfield.ac.uk

**Summary**

*The soil profile analytical database (SPADE) was developed to add value to the European soil geographical database legend and harmonize European soil profile analytical information. The initial data collection phase for the EU-15 (SPADE-1) had limitations due to lack of profile data and explicit links to the soil mapping units in the geographical database. A second phase (SPADE-2) of data acquisition provided a more extensive coverage of the soil typological units in the EU-15, covering primary soil properties, in particular variables necessary for pan-European assessment and environmental modeling. An extension of SPADE-2 is in progress that includes requests for data from old and recent member states, and accession and candidate countries that will expand the geographical extent into South-eastern and central Europe and the Baltic states. SPADE-1 is currently available as a database within the Soil Geographical Database of Europe version 1.0 and SPADE-2 at present has restricted circulation, but will form part of Soil Geographical Database of Europe version 3.0, available from the European Soil Bureau Network at the European Commission Joint Research Centre, Ispra.*

## XII.1 Background SPADE-1

The Soil Profile Analytical Database (SPADE) 1 forms part of the Soil Geographical Database of Europe (SGDBE) version 1.0 developed by and available from the European Soil Bureau Network at the European Commission Joint Research Centre (JRC), Ispra [http://eusoils.jrc.it/esbn/Esbn_overview.html]. Essentially the database is structured around a digital version of the 1:1,000,000 European soil map that describes the spatial distribution soil mapping units (SMUs) as individual polygons. This can be used in the geographical information software ArcView (v. 3.2, 8.3) or ArcGIS (v. 8.2, 8.3). Linked to the SMUs are a number of database tables that describe the proportion and attributes of each soil typological unit (STUs) that comprise each individual SMU, but not the spatial distribution of the STU within the SMU as this is not achievable at the map scale of 1:1,000,000. Additional database tables linked to the SGDBE include a set of pedotransfer functions for soil hydraulic properties (HYPRES), and the SPADE-1 database is used in conjunction with one set of pedotransfer functions in HYPRES to derive Mualem- van Genuchten hydraulic parameters for the STUs.

### *XII.1.1 Data providers and data organisation SPADE-1*

Fifteen member states (EU-15) provided data for SPADE-1 (Austria, Belgium, Denmark, Eire, France, Finland, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and U.K) that focused on providing primary attributes for extensive and important soil types (level 1) for each country. The characterised STUs for SPADE-1 were the dominant STU within the most extensive SMUs and only those under agricultural land use. Soil properties for each horizon include the following, although in many cases data was not available for all the criteria:

- texture (particle size classes)
- organic matter content
- structure
- total nitrogen
- pH
- ESP or SAR
- calcium carbonate content
- calcium sulphate content
- electrical conductivity
- CEC and exchangeable bases
- soil water retention

- bulk density
- rooting depth
- groundwater level
- parent material

Two types of formats were used to capture the profile data for the specific STU:

- *An 'estimated' dataset*, derived from measured data in combination with expert judgement, provides a true representation of the soil profile analytical characteristics for a particular soil type associated with an STU and is not related to a specific geographical location.
- *'Measured' dataset* of data from a georeferenced profile location but may not be truly representative of the soil type indicated by the STU on the map.

The estimated dataset is used in the link between analytical data and the spatial geographical database, and although in part may be estimated from expert judgement, is more truly representative of the STU. This information is more suitable than the georeferenced profile data for pan-European environmental assessment and modeling at the 1:1,000,000 scale. Associating the profile data with the spatial SGDBE was achieved through a process of assigning an 'explicit' or 'implicit' link to the SMUs. An 'explicit' link is supplied directly by the data provider, where the profile data is linked to a specific SMU or SMUs. The profile data is then associated with the dominant soil in the selected SMUs for that country. An 'implicit' link is developed where the data provider does not give an indication of the associated SMU but the profile matches the dominant soil in SMUs for that country provided the STU attributes of SOIL (soil type), COUNTRY, and TEXT1 (dominant surface texture) are met. 'Explicit' links have higher priority over 'implicit links due to the more reliable association developed specifically by the expert judgement of the data provider.

### *XII.1.2 Applications of SPADE-1 data*

SPADE-1 data has been used as soil property input into **EuroPEARL** to assess pan-European pesticide flux and potential leaching to groundwater for particular pesticide-crop combinations (Titak *et al*., 2004). The authors highlighted some of the difficulties and limitations of limitations of SPADE-1 data, which were already identified by the SPADE working group and are discussed in the following section. Acquisition of measured soil carbon data is also in demand for evaluation of pedotransfer rules used to derive the European topsoil organic carbon map (OCtop) (Jones *et al*., 2004). The SPADE database (although limited in phase 1) provides harmonised organic carbon data for STUs and the expansion of the dataset (SPADE-2) provides a greater number of measured values of organic carbon under different land uses that can be used to further verify OCtop.

### *XII.1.3 Limitations of SPADE-1 data*

A number of factors limit the application of SPADE-1 data for pan-European modeling:

- Three of the EU-15 countries (Austria, Finland and Sweden) were unable to provide profile data
- Only 240 profiles have either an 'explicit' or 'implicit' link to a soil mapping unit (equivalent to 8% of the total STUs for the EU-15)
- For STUs with a designated dominant arable land use only 78 are linked to profile data giving rise to only a 6% of assigned arable land with associated profile analytical data.

## XII.2 SPADE-2

In light of the limitations discussed in the preceding section, a second acquisition phase for profile data was implemented that was sponsored by the European Crop Protection Association (ECPA) with support from the European Soil Bureau at JRC. SPADE-2 was developed as an additional profile dataset to be used in association with the spatial SGDBE. The primary aim was to expand the 'estimated' profile data for dominant and secondary land uses of all STUs in SGDBE v 3.2.8 for all EU member states. The following soil properties were requested to provide primary data required for modelling purposes:

- particle size (clay%, silt%, fine sand%, medium sand%, coarse sand%)
- organic carbon (%)
- pH
- bulk density

### *XII.2.1 Data providers and data derivation SPADE-2*

After approaching potential data suppliers through the European Soil Bureau Network and subsequent negotiations the following countries supplied data for SPADE-2: Belgium & Luxembourg, Denmark, England, Wales & Northern Ireland, Finland, Germany, Italy, Netherlands, Portugal and Scotland supplied data (Fig. XII.1).

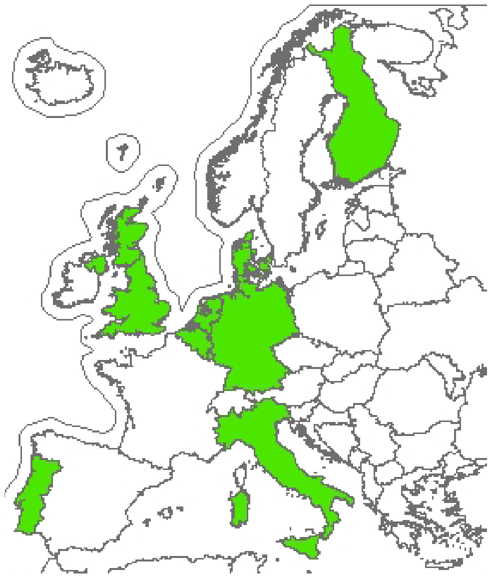

**Fig. XII.1. Countries supplying data to SPADE-2.**

Data was requested from providers using prescribed spreadsheet templates for country-specific SMUs and STUs. Two spreadsheets were given to each data provider to aid capture of profile analytical data:

- List of country-specific SMUs and associated STU attributes in SGDBE v 3.2.8 (spreadsheet 1)
- List of SMUs and associated STUs with blank data fields to be completed by the data suppliers (spreadsheet 2)

Spreadsheet 1 details SMU and associated STU attributes (soil type, parent material, land use, texture, etc.) which provides the data supplier with information to guide the selection of an explicit link between profile analytical data to an appropriate STU within the SMU. This ensured that more profiles were directly associated with STUs compared with SPADE-1 data. Analytical data is captured in Spreadsheet 2 by the data provider.

**Table XII.1. Comparison of data between data suppliers.**

| *Country* | *Clay (mm)* | *Silt (mm)* | *Sand 1 (mm)* | *Sand 2 (mm)* | *Sand 3 (mm)* | *Organic carbon* | *pH* |
|---|---|---|---|---|---|---|---|
| Belgium & Luxembourg | 0.002 | 0.05 | 0.2 | 0.5 | 2 | WB[a] | $H_20$ |
| Denmark | 0.002 | 0.05 | 0.2 | Not used | 2 | WB | $H_20$ |
| England, Wales & N. Ireland | 0.002 | 0.06 | 0.2 | Not used | 2 | WB / Dr C[b] | $H_20$ |
| Finland | 0.002 | 0.06 | 0.2 | 0.6 | 2 | WB / Dr C | $H_20$ |
| Germany | 0.002 | 0.06 | 0.2 | 0.6 | 2 | WB / Dr C | $H_20$ |
| Italy | 0.002 | 0.05 | 0.25 | 0.5 | 2 | WB | $H_20$ |
| Netherlands | 0.002 | 0.05 | 0.105 | 0.21 | 2 | WB | KCl |
| Portugal | 0.002 | 0.05 | 0.2 | Not used | 2 | WB | $H_20$ |
| Scotland | 0.002 | 0.05 | Not used | Not used | 2 | CHN[c] | $H_20$ |

a Walkley-Black (1934) method.

b Dry combustion (loss on ignition) – peat soils only

c CHN analyser.

Mean and standard deviation values were requested for the particle size fractions, pH and organic carbon but not for horizon depth and bulk density. Analytical methods for used for derivation of pH, organic carbon and bulk density data were also specified by the data provider. Equivalent spherical diameters for the particle size fraction thresholds for each particle size class were also noted because many national schemes differ from the FAO particle size fraction classes. Detailed protocols for completing spreadsheet 2 are described in Hollis et al. (2006).

### *XII.2.2 Data harmonisation*

Initial data was checked for errors (e.g. Σ all particle size fractions between 99 and 101%) and Table XII.1 details the difference between particle size class thresholds and analytical methods for the primary soil properties from the data suppliers. Evidently harmonisation of particle size data was necessary to ensure appropriate collation of data at a European level. It was not necessary to harmonise organic carbon or pH data.

### *XII.2.3 Particle size distributions*

Particle size data was converted to a log Φ value:

$$\Phi = -\log_2 d = -\{\log_{10} d / \log_{10} 2\} \quad (1)$$

where d – is the equivalent spherical diameter

A monotonic cubic spline interpolation procedure between data points was used to extract the appropriate proportion at each of the FAO standard particle size classes. A very good fit between measured and interpolated particle size distributions was achieved for the majority of data supplied (Fig. XII.2).

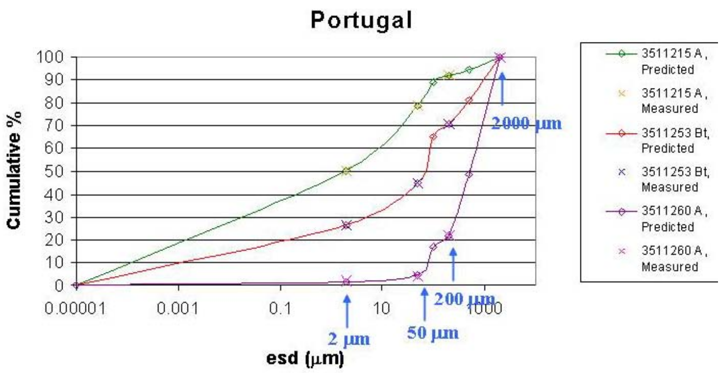


**Fig. XII.2. Comparison between measured and interpolated particle size distributions for an STU in Portugal.**

However, in a few cases where particle size distributions were very skewed, the interpolation did not perform well (Fig. XII.3). In these cases, for example when the interpolated values were negative, the data was corrected manually in reference to the original supplied data.

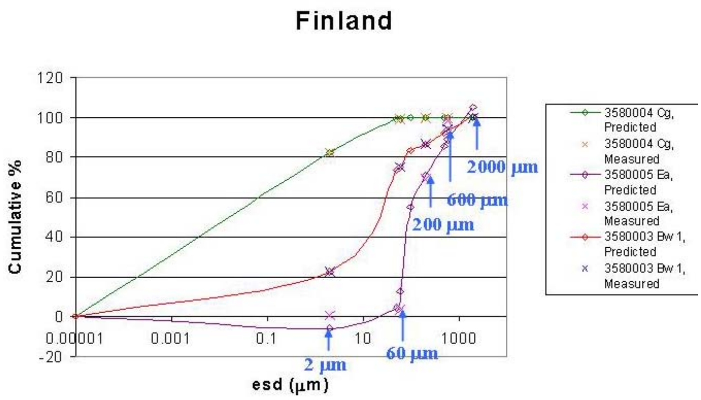


**Fig. XII.3. Comparison between measured and interpolated particle size distributions for an STU in Finland with skewed particle size distributions.**

### *XII.2.4 Data validation*

A validation check of particle size (derived interpolated data), pH, organic carbon and bulk density data was implemented to ensure data consistency. Bulk density data was compared with organic carbon and sand contents and after some initial adjustment of outliers showed expected relationships. Statistical comparisons of particle size data indicated that the interpolation procedure predominantly gave very reliable results for the main particle size fractions (clay, silt, sand). The values for the individual sand size fractions were less reliable, particularly for England and Wales, Belgium & Luxembourg and Italy. Organic carbon frequency distributions were compared between 3 distinctive soil types to identify whether trends in the data were similar to expected organic carbon contents in contrasting pedogenic environments.

Comparisons of soil organic carbon content and frequency distributions showed expected trends of lower organic carbon content in free-draining non-organic topsoils compared with gleyed 'wet' (seasonally waterlogged) soils. Larger organic carbon contents were evident in Podzols, where organic matter accumulation is enhanced by high acidity. Trends in pH data showed expected spatial distributions across Europe linked to soil climate and parent material (Fig. XII.4), and do not show any unusual outliers beyond pH range 2.5 to 9.

## XII.3 SPADE-2 data structure

SPADE-2 data characterises virtually all STUs within the SMUs of Belgium, Denmark, England, Finland, Germany, Italy, Luxembourg, Netherlands, Portugal, Scotland and Wales, representing about 35% of the total STUs of the EU-15. SPADE-2 profile data is stored as a dbf file with STU and SMU identifiers with the corresponding dominant and secondary land use analytical data. The STU identifier is used to link the database to the spatial polygons in SGDBE so that attributes can be mapped at a European level. The individual STUs within the SMU are not however spatially differentiated and information only exists on the proportion of each STU within the SMU and hence mapping and analysis should take this into account accordingly. Linking SPADE-2 database to the map polygons is achieved through assigning a spatial join through a relational table (STU.org) between SPADE-2.dbf and the polygon attribute table. The specific process of linking the SPADE-2.dbf to the map and quantifying areas of selected soil/land use types in ArcView of ArcGis platforms is set out in detail in Hollis *et al*., 2006.

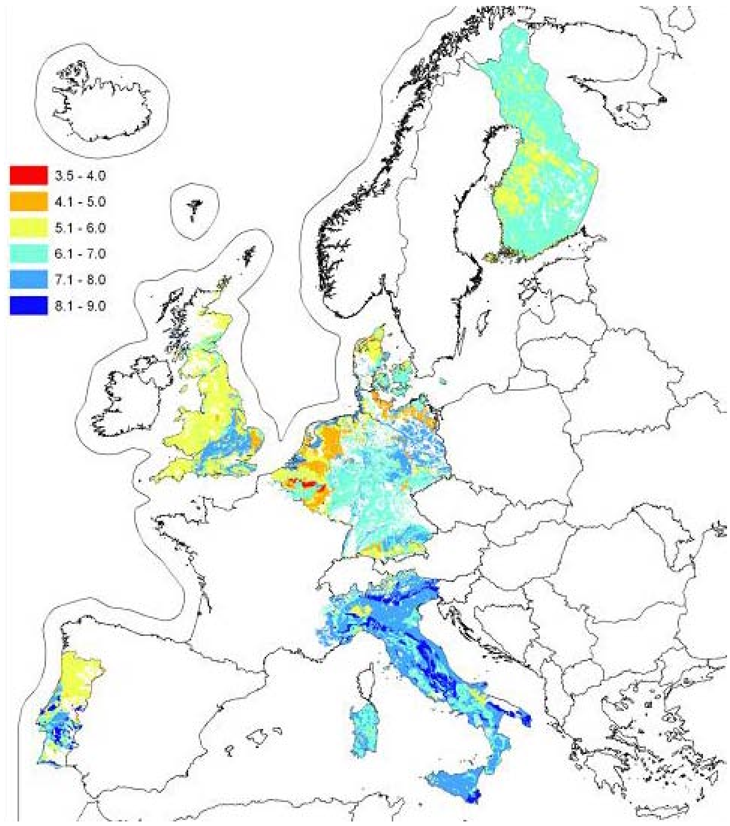


**Fig. XII.4. Topsoil pH of the dominant agricultural STU within an SMU from SPADE-2 data.**

**Fig. XII.5. Countries contributing data to SPADE-2 (dark green) and countries approached to supply data for the SPADE-2 extension (light green).**

### *XII.3.1 SPADE-2 access and documentation*

SPADE-2 will be distributed in the future on CD-ROM as part of the European Soil Database v 3.0. Raw data and SPADE-2.dbf is currently only available by restricted distribution. The data protocols[7] for SPADE-2 are described in detail in Hollis et al. (2006). The National Soil Resources Institute at Cranfield University, U.K. currently coordinates the SPADE-2 data acquisition programme with support from the European Soil Bureau Network, Joint Research Centre, Ispra, Italy.

### *XII.3.2 SPADE 2.1-extension*

Although SPADE-2 shows significant improvement on STU coverage there are still information gaps at the European level. A second phase for SPADE-2 has been developed sponsored by ECPA with support from the European Soil Bureau at JRC. The extension includes acquisition of data from older member states, recent member states, accession and candidate countries to expand the dataset into central Europe. The countries approached to supply data cover SE Europe, central Europe and the Baltic States (Fig. XII.5). Countries at that have indicated positive responses include Bulgaria, Hungary, Lithuania, Poland, Romania, Slovakia and Switzerland. Greece has also indicated the possibility of supplying data. Data acquisition is planned to be completed by the third quarter of 2007. The countries approached to supply data have been provided with spreadsheets 1 and 2 for their specific countries. Data harmonisation and validation procedures will be followed in the same manner as the original SPADE-2 project.


## Acknowledgements

*We thank ECPA for continued financial support for the SPADE 2 extension and colleagues from the European Soil Bureau Network that provided and have indicated willingness to provide data support for all phases of the SPADE programme. Encouragement and support is greatly appreciated from the Institute of Environment and Sustainability, Joint Research Centre, Ispra, Italy.*


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# XIII. Digital Soil Mapping at work: interpolation of soil parameters for the Danube river basin

Tomislav Hengl, Hannes I. Reuter and Luis Rodriguez-Lado

Land Management and Natural Hazards Unit
European Commission, Directorate General JRC, Institute for Environment and Sustainability, TP 280, Via E. Fermi 1, I-21020 Ispra (VA), Italy
Tel.: + 39 0332 785535; Fax: + 39 0332 786394
tomislav.hengl@jrc.it; hannes.reuter@jrc.it; luis.rodriguez-lado@jrc.it

**Summary**

*This chapter proposes methodology to build a soil-based GIS of Danube river basin by using the state-of-the-art digital soil mapping techniques and reports on some preliminary results. This methodology will demonstrate a full capacity of using digital soil mapping procedure to improve semantic and geographical detail of existing soil geographical data at paneuropean scales and will demonstrate that JRC is capable of producing the value-added maps that fit the decision-making needs of European Commission. Soil variables will be interpolated using regression-kriging and techniques alike that can employ a large quantity of predictors, ranging from DEM parameters, remote sensing indices (MODIS Enhanced Vegetation Index) and polygon-based maps (1:1M soil and geological maps). All target soil variables will be mapped at two resolutions: 250 m (basic) and 1 km (generalized); both aligned with the INSPIRE reference grids. The final outputs will be five groups of soil variables: (1) Soil types – WRB group and sub-group; (2) Soil texture – clay, silt and sand content, texture classes; (3) Soil fertility – soil organic carbon; (4) Parent material – parent material type, depth to parent material, depth to obstacle to roots; (5) Soil hydrological properties – groundwater depth. The final SIS of Danube river basin will have an open structure, so that it will be possible to update the maps with additional new profiles and predictors of higher quality (better resolution, better spectral coverage). The project outputs should popularize DSM concepts and role of the JRC's DSM team and motivate also other national DSM agencies to participate with their own resources, so that the applications can be extended over the whole continent.*

## XIII.1 Backgrounds

There has been an increasing interest in the use of semi-automated Digital Soil Mapping (DSM) techniques to improve the semantic and spatial quality of existing soil information (McBratney et al, 2003; Dobos et al. 2006). Most of these techniques rely on the high quality profile observations and flexible interpolation techniques. In the case of the Danube river basin, almost 10,000 profiles have already been collected and are available in a common soil profile database (Jones R. et al. 2005). This large quantity of soil profiles can now be used to make predictions of the key soil variables over the whole area of interest at relatively fine scales (250 m). In addition, a large quantity of detailed environmental predictors (SRTM DEM, MODIS images), which can be used to improve the spatial detail of existing soil maps, is now available at no cost.

During the Global Workshop on Digital Soil Mapping, that was held in September 2004 in Montpellier, an interesting discussion[8] has raised the temperature in the Lamour hall of the INRA campus are traditional soil maps of much use for today's applications and do we need soil classification systems at all, or should we focus on only interpolating analytical soil properties? In principle, we have put our selves in the neutral group (*let's burry the hatchet*), which thinks – yes! the soil-class data including the soil type data is useful as long as it is produces using consistent and unbiased methodology. Fieldwork should remain a vital and irreplaceable part of the soil mapping.

Although many pedometrics techniques are well-explained in the literature, their implementation is still a bottle-neck and the most national and regional soil mapping and monitoring teams in the World still rely on traditional techniques (Lagacherie et al. 2006). This makes this project especially important because we want to prove that semi-automated DSM techniques are fit for real mapping projects and that they are operational to deliver high quality soil information products. In this context, this project aims to popularize DSM concepts and role of the JRC's DSM team and motivate also other national DSM agencies to

[8] See also Pedometron newsletter #17 available at [www.pedometrics.org].

participate with their own resources so that the applications can be extended over the whole continent or even at global scales [see also www.globalsoilmap.net].

An extensive example of how the DSM techniques can be applied to map various soil variables is the one of the Australian Soil Resources Information System. In this case, the soil mapping team used a large number of predictors (terrain descriptors, climatic images, lithology, Landsat multispectral imagery and land use maps) to map a number of soil variables (textures, soil thickness, pH, organic carbon etc.) [http://audit.ea.gov.au/anra/]. To illustrate the computational complexity of this procedure, we should also mention that there were almost 150,000 soil profiles and over 50 predictors (GIS layers) used for derivation of soil-property maps. The statistical model applied was regression-trees, which has the advantage of being able to incorporate both continuous and discrete information (Henderson et al., 2005).

## XIII.2 Methods and materials

Objective of this project is to build a professional soil-based GIS at resolution of 250 m by using the state-of-the-art DSM techniques called regression-kriging (Hengl et al. 2007a), which can then be used for the purpose of the pan-**European Flood Alert System EFAS** [http://efas.jrc.it/] and similar applied pan-EU projects such as **BIOSOIL**, **LUCAS**, **Geochemical Atlas of Europe** [www.gsf.fi/publ/foregsatlas/] and similar. This would promote the work that has already been done at JRC considering pan-European mapping of soils and soil related properties.

### *XIII.2.1 Inputs*

There are three groups of inputs that will be needed for implementation of this project: (a) **soil profiles** (Fig. XIII.1); (b) **remote-sensing and topography-based predictors** and (c) polygon-based **thematic maps** (soil and geology).

**Table XIII.1. Status of the soil profile database (on 13/01/2007).**

| | **Number of profiles** | **Total land area (*km*$^2$)** | **Density (prof./*10*$^3$ *km*$^2$)** |
|---|---|---|---|
| Available countries | | | |
| AUSTRIA | 1668 | 82,444 | 20.2 |
| BULGARIA | 1250 | 110,550 | 11.3 |
| BOSNIA-HERZEGOVINA | 481 | 51,129 | 9.4 |
| CROATIA | 2198 | 56,414 | 39.0 |
| CZECH REPUBLIC | 1201 | 77,276 | 15.5 |
| HUNGARY | 1190 | 92,340 | 12.9 |
| ROMANIA | 1201 | 230,340 | 5.2 |
| SLOVAK REPUBLIC | 1954 | 48,800 | 40.0 |
| SLOVENIA | 70 | 20,151 | 3.5 |
| Missing countries | | | |
| GERMANY (Bavaria) | | 70,548 | |
| MOLDOVA | | 33,371 | |
| SERBIA | | 102,136 | |
| UKRAINE | | | |
| *Total* | 11078 | | |

As can be seen from Table XIII.1 and Fig. XIII.1, almost all of the profiles in the Danube river basin are already available (11078 profiles at the moment). The biggest uncovered areas are in Serbia, and Bavaria. Collection of the remaining datasets is under way, but this is a slow process because JRC typically needs to by rights to use these data. In the optimal situation, the national DSM groups should provide the data at no costs, but then hold rights to use all JRC value-added products derived from such data. This can be implemented through a web-application interface where all members of the gross DSM team would be able to login and access the most recent data. Although there has been already some negotiation in this direction, the unclear data sharing policies still remain one of the biggest bottlenecks.

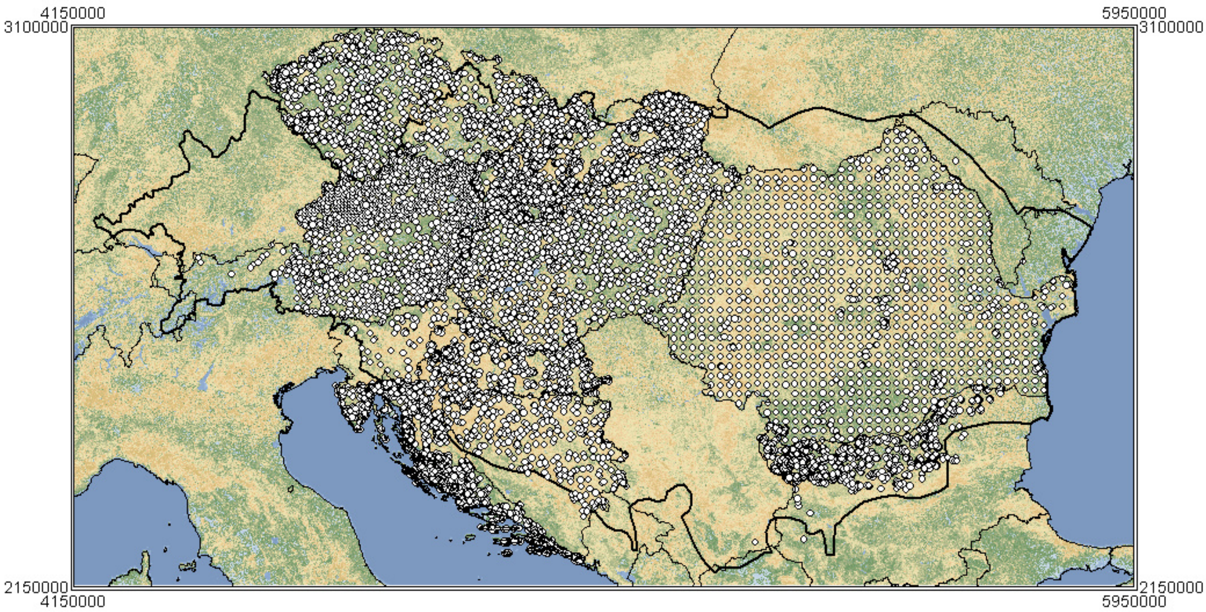


**Fig. XIII.1. Soil profile database of the Danube river basin with a total of 11078 profiles. The missing datasets, at the moment, are the south-eastern Germany, complete territory of Serbia and small parts of Ukraine and Moldavia.**

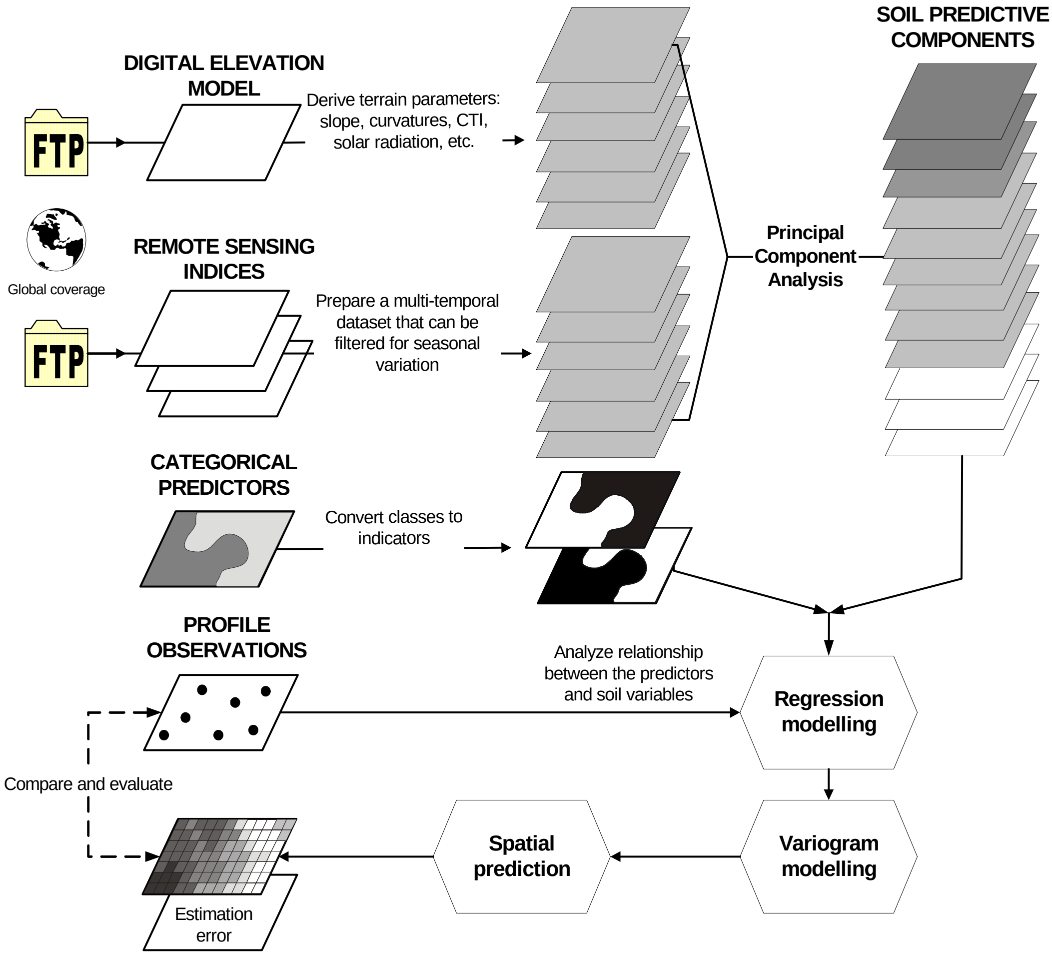


**Fig. XIII.2. Example of data-flow used to interpolate soil variables from profile observations using auxiliary information. After Hengl et al. (2004).**

As remote sensing and topography-based predictors, we will use the following layers:

1. **Auxiliary topographic and climatic variables** (to be derived from SRTM DEM and the MARS point database) used as predictors: Elevation, Slope, Incoming solar radiation, Wetness index, Curvatures, Memberships to generic landform shapes, Climatic variables (mean annual temperature and std., mean annual rainfall and std., number of days under snow etc.).
2. **Auxiliary remote sensing imagery** used as predictors: The Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index (EVI) components derived from the multitemporal dataset of EVI's, Moderate Infrared (MIR) bad of the MODIS images.
3. **Auxiliary polygon maps** used as predictors: soil map of Europe at scale 1:1M.

We will use the regression-kriging technique and the methodological framework described in Fig. XIII.2. The focus will be given on mapping five groups of soil variables (Finke et al. 2001):

- **Soil types –** WRB group and sub-group;
- **Soil texture –** clay, silt and sand content, texture classes;
- **Soil fertility** – soil organic carbon;
- **Parent material** – parent material type, depth to parent material, depth to obstacle to roots;
- **Soil hydrological properties –** groundwater depth;

Soil types will be interpolated separately so that each soil category will be presented in a separate map using membership values. In R package, we can predict soil-class observations as the target variables using soil predictive components (SPCs) as predictors: `soilclass.fit <- multinom(soilclass ~ spc1+spc2+...+spc(p), data=danube)`. The **nnet** package will then iteratively estimate coefficients for all predictors, which can be used to map odds of observing each class (Hengl et al. 2007b). Technically speaking, the procedure can be summarized as follows:

- obtain the auxiliary images from FTP servers;
- convert categorical predictors to indicators;
- resample all predictors to a common grid and derive predictive components (SPCs);
- fit the target soil variables (WRB groups) using SPCs and indicators and make predictions for the whole case study;
- visualize the most probable class and evaluate the prediction capabilities using the validation set;

At this moment, we have already obtained the MODIS imagery and prepared the SRTM DEM of the area. The MODIS images were obtained at no charge from the Earth Observation System Data Gateway [http://edcimswww.cr.usgs.gov]. The order can be done following these steps. First, download the files using the WGET software since it allows automating the process. Nine single blocks are necessary to cover the whole Danube Basin. Each single block is 495.209 KB in size, thus a complete 16 days scene for the Danube basin loads 4.25 GB. The download speed obviously depends on the network. In our case the speed in the JRC network was approximately 200 KB/s. The average time to download a single block is about 40 minutes. We have downloaded the 16 day blocks for the whole Danube Basin in the period comprised between 01/01/2004 and 14/09/2006. That makes an amount of 585 single blocks with a total load of 276.25 GB. The nine blocks comprising each 16 day period were mosaicked using the Command Line in the "Modis Tools"software. The mosaics can be generated using a batch file as follows. First, create a batch file for the mosaic of 16 days scenes:

```
mrtmosaic -i i20050829.prm -s "0 1 0 0 0 0 0 1 0 0 0" -o tmp20050829.hdf
```

Where "mrtmosaic" is the mosaicking command; i20050829.prm is a parameter file indicating the files (blocks) to be mosaiqued (Table 3); "0 1 0 0 0 0 0 1 0 0 0" indicates that only the 2nd (EVI) and 8th (MIR) bands will be mosaicked; tmp20050829.hdf indicates the output filename. The content of the prm file for the mrtmosaic option is:

```
E:\2005\2005.08.29\MOD13Q1.A2005241.h18v03.004.2005263110759.hdf
…
E:\2005\2005.08.29\MOD13Q1.A2005241.h20v04.004.2005262014209.hdf
```

The original blocks, and thus the resulting mosaics, are represented in Integerized Sinusoidal Projection. We must reproject these mosaics to the Lambert Azimutal Equal Area (LAEA_ETRS89) according to INSPIRE requirements. This conversion cannot be directly performed in Modis Tools. We must first reproject the mosaic files to Geographic using the resample command in Modis Tools and then reproject the Geographic mosaics to LAEA_ETRS89 using another conversion tool. An example of a reprojection file from Sinusoidal to Geographic coordinate system is:

```
resample -p 20050202.prm
…
resample -p 20050610.prm
```

The parameter file (20050202.prm) required in the first line of the previous batch file is:

```
INPUT_FILENAME = F:\Modis\order_mos_sin\Tmp20050202.hdf
SPECTRAL_SUBSET = ( 1 1 )
#ORIG_SPECTRAL_SUBSET = ( 0 1 0 0 0 0 0 0 1 0 0 0 )
SPATIAL_SUBSET_TYPE = INPUT_LAT_LONG
SPATIAL_SUBSET_UL_CORNER = ( 50.98571 7.5643 )
SPATIAL_SUBSET_LR_CORNER = ( 40.55686 29.38015 )
OUTPUT_FILENAME = E:\2005\20050202geo.hdf
RESAMPLING_TYPE = BILINEAR
OUTPUT_PROJECTION_TYPE = GEO
OUTPUT_PROJECTION_PARAMETERS = (
 0.0 0.0 0.0
 0.0 0.0 0.0
 0.0 0.0 0.0
 0.0 0.0 0.0
 0.0 0.0 0.0 )
DATUM = WGS84
```

Finally use the FWTools software to reproject the Geographic mosaics to LAEA_ETRS89. In this case the output files are in tif format. A batch file to do this is:

```
gdalwarp -s_srs EPSG:4326 -t_srs EPSG:3035 -tr 250 250 HDF4_EOS:EOS_GRID: "20041218geo.hdf":
MODIS_Grid_16DAY_250m_500m_VI: "250m 16 days EVI" F:\modis\EVI_MIR_2005tif\20041218mosaicEVI.tif
```

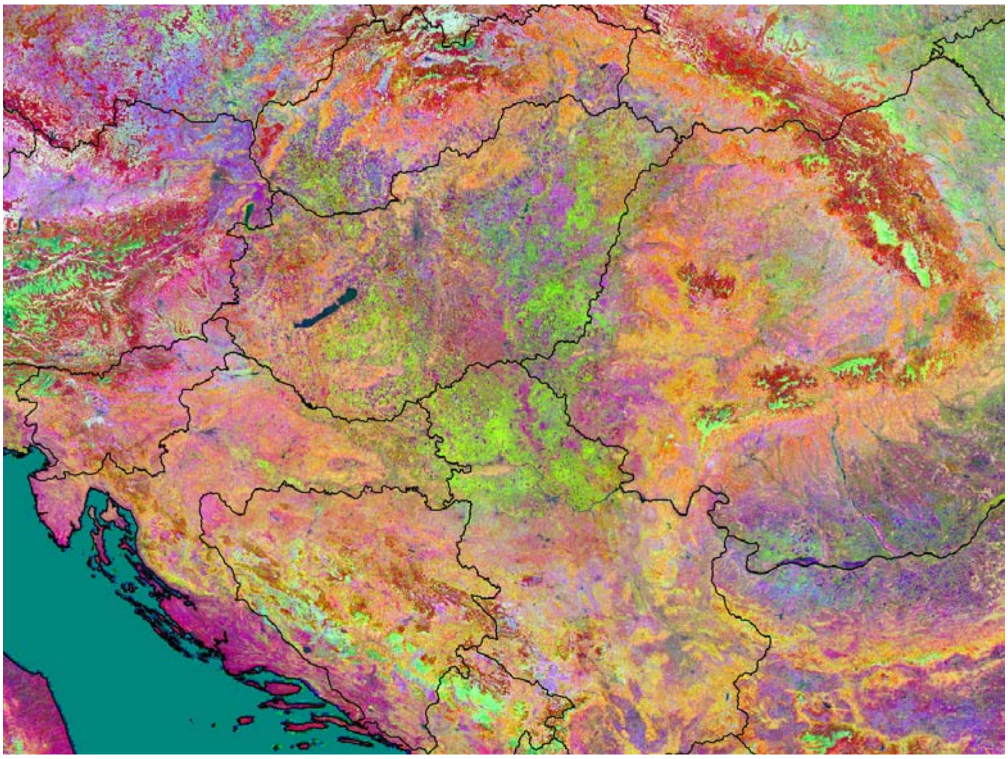

**Fig. XIII.3. The false-colour composite of Danube basin derived using first three principal components of 18 EVI images (period 2005-2006). The long-term components of EVI images have shown to be efficient in quantitatively representing the vegetation and land use types. The first component (red colour) reflects the overall mean biomass, the second component (green) reflects the speed of rotation of crops and the third component (blue) reflects the variations in climate.**

### *XIII.2.2 Outputs*

We plan to interpolate all soil variables at two grid resolutions: **the basic grid resolution of 250 m** and **the generalized grid resolution of 1 km**. Note that we will use a similar grid definition that was used to produce the LANDCOVER map of Europe, which is distributed by EEA [www.eea.eu.int]. We will also make sure that the final products are INSPIRE [http://inspire.jrc.it/] compliant, i.e. that a proper grid definition[9] and metadata description are used.

In contrary to the DSM work done by the Australian team (Henderson et al. 2005), we will also consider the spatial location of profiles (i.e. geostatistical analysis of profiles) during the spatial prediction. This should allow us to achieve higher spatial prediction power and represent more smooth changes of soil variables. We can anticipate that this will improve predictions especially in the areas where relatively high (or low) values have been measured (hot spots).

The WRB soil-class field designations will be used to produce membership maps[10] for each soil category (WRB soil group) and also following the regression-kriging model as explained in (Hengl et al. 2007). In the first version of the SIS, we will map WRB soil groups over the whole Europe (extrapolation) and then mask out the countries and areas that did not participate in the project. This will motivate these countries to participate in this project actively and offer their resources. The specific outputs of this project will be:

- #1: **A Soil Information System of the Danube river basin** (DVD) with soil layers (raster images), with the description of the data and detailed instructions on how to use the data and for which purposes.

- #2: **EU technical report** “User manual for spatial prediction of soil variables at pan-European levels”, authors Hengl T., Rodriguez-Lado L., Reuter H.I.,

- #3: **Web-application** (for registered users) under eusoils.jrc.ec.europa.eu where all information about this project can be found, including the data browser.

The final SIS of Danube river basin will have an open structure (object-oriented GIS), so that it will be possible to update the maps with additional new profiles and predictors of higher quality (better resolution, better spectral coverage). Ideally, these project outputs should popularize DSM concepts and role of the JRC’s DSM team, and motivate also other national DSM agencies to participate with their own resources (soil data, expertise, personnel), so that the application can be extended over the whole continent.

## XIII.3 Project phases

| | |
|---|---|
| **PHASE #1: Preparation of predictors** | Preparation of the DEM of the Danube river basin and key terrain parameters; |
| | Preparation of the multitemporal data set of MODIS images for three year period; |
| | Preparation of soil and geology-based polygon maps and water mask for the same area; |
| | Preparation of the quality criteria to evaluate the final outputs; |
| **PHASE #2: Preparation of soil variables** | Preparation of soil profile database and filtering of type errors and outliers; |
| | Transformation of variables to achieve normality of distributions; |
| **PHASE #3: Geo-statistical analysis** | Regression analysis: predictors vs target soil variables; |
| | Fitting of variograms for residuals; |
| | Fitting of soil-classes using neural networks; |
| **PHASE #4: Spatial prediction and simulations** | Design of the interpolation algorithms (scripts); spatial prediction and analysis in software (GSTAT/SAGA); |

[9] INSPIRE reference grids are available in Annoni (2005); coordinate system used is: ETRS89 Lambert Azimuthal Equal Area.

[10] The difference between the Soil-class map of Europe and Map of Europe at scale 1:1M (Jones A. et al. 2005) is that the soil-class map represents objectively derived predictions of soil-classes per pixel and the traditional soil map of Europe shows only polygons of assumed soil-class associations.

| | |
|---|---|
| **PHASE #5: Filtering and cross-checking of the outputs** | Evaluation of the results and accuracy of predictions; |
| | Detection of data-errors and artefacts; |
| | (optional) Improvement of the spatial prediction models; |
| | Preliminary products will be first time presented at the next ESBN workshop. |
| **PHASE #6: Post-production (promotional materials, DVD and publications) SIS of Danube river Basin V1.0** | The final products will include: |
| | DVD with all data at resolutions of 250 m and 1 km and accompanied user guides; |
| | **Posters and brochures** that will be shared at ESBN and similar DSM meetings; |
| | Guidelines to use Soil-class map of Europe CD (several co-authors) – JRC technical publication; |

Based on the interest of the countries-collaborators, the database will be further on periodically upgraded. The idea is to build a web interface where various agencies would be able to submit additional or corrected profiles. Then, the system would automatically update the prediction models (re-run interpolation procedure) to produce updated images. The most recent database would be then always available to all registered users.

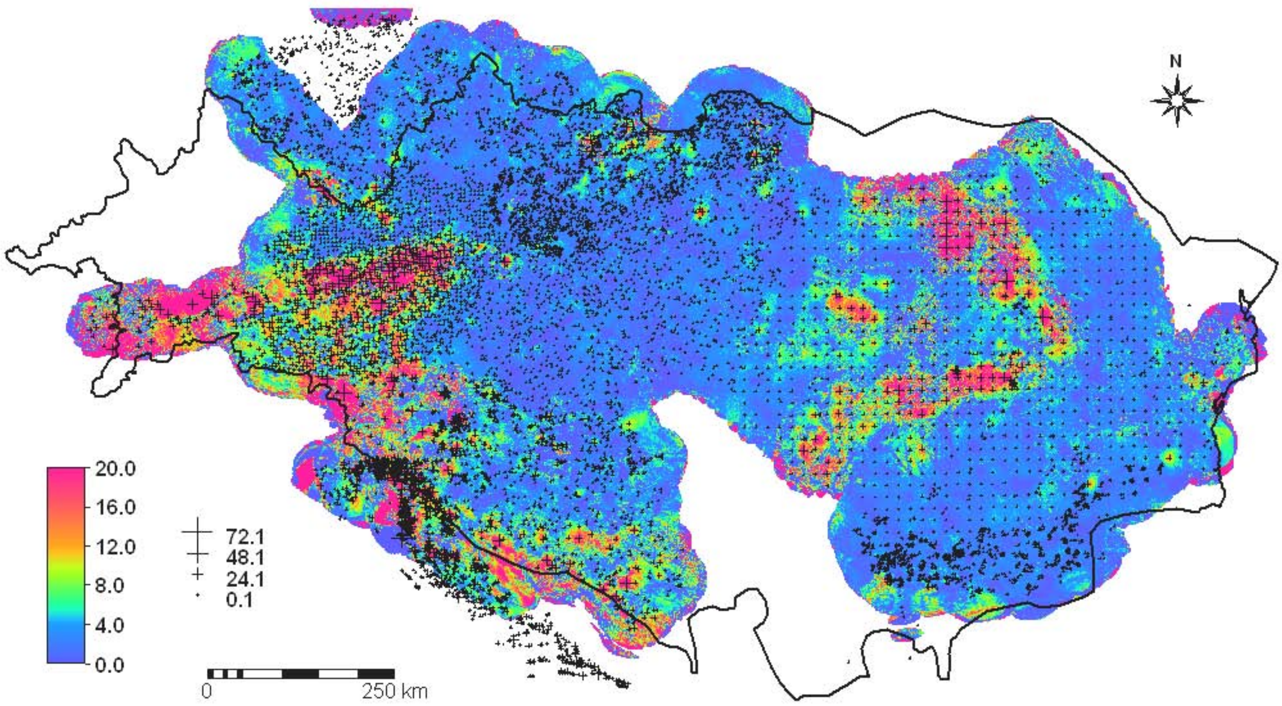


**Fig. XIII.4. Humus content in topsoil (%) interpolated at 1 km grid.**

## XIII.4 Preliminary results

The following section presents some preliminary results for mapping clay and humus content in topsoil in SAGA GIS. The results of interpolation by RK can be seen in Fig. XIII.4 and Fig. XIII.5. In the case of mapping humus, predictors such as elevation, wetness index and EVI indices are all significant predictors and the final pattern confirms that the high humus content is, in general, connected with the distribution of the coniferous mountainous forests. In the case of mapping clay content, the distribution of values seems to be more complex and can not be explained well with the list of current predictors. This clearly illustrate that some soil variables will be easy to map, while to other might not comply with the required accuracy/detail. We expect that the final outputs will improve once all auxiliary predictors, including the parent material map, are prepared.

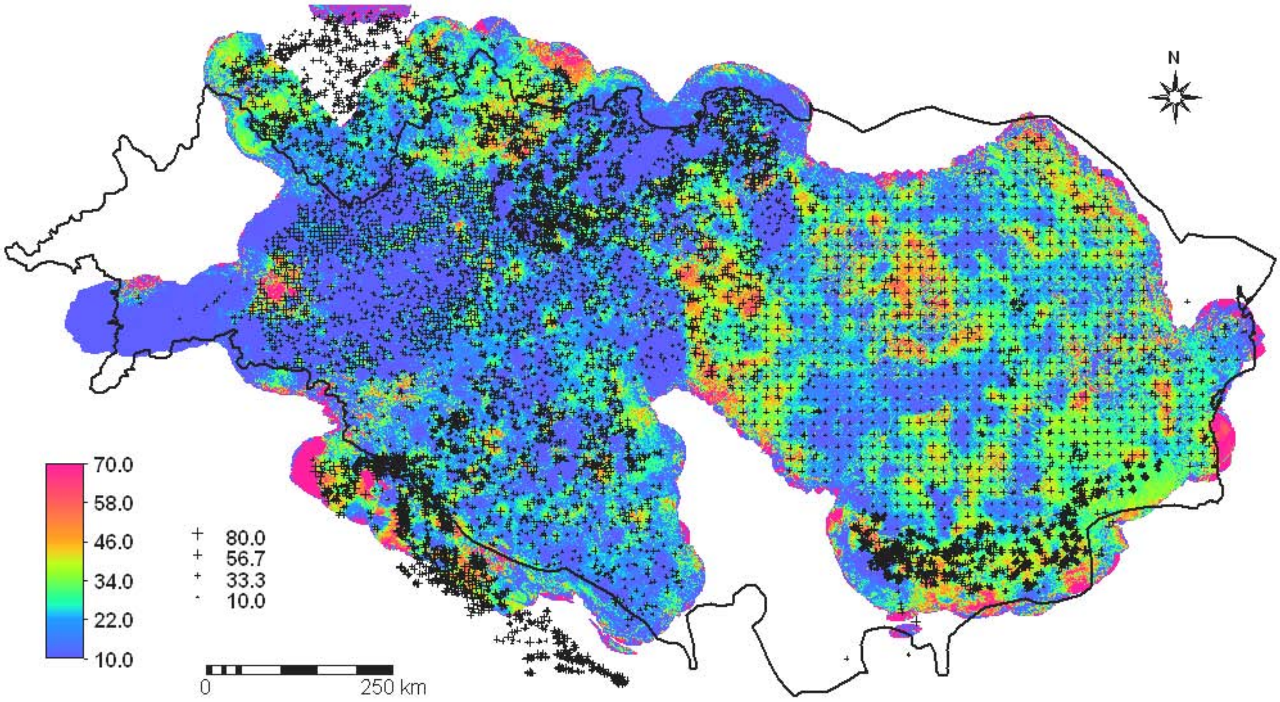


**Fig. XIII.5. Clay content (%) in topsoil interpolated at 1 km.**

## XIII.5 Discussion

Although many traditional soil mappers (boundaries drawn manually) already claim to be able to represent spatial distribution of soil types accurately, there are two major deficiencies with most of the traditionally done soil maps in the world: (1) traditional soil maps do not actually show location of soil types but location of soil mapping units that typically contain two or more soil types, (2) the spatial detail of the traditional soil maps is typically too coarse for decision making and often does not satisfy the prescribed cartographic criteria. We believe that digital soil mappers need to work together with the experienced soil surveyors to develop hybrid techniques that can bridge the gaps between the traditional and pedometrics groups of researchers. The motives to develop a robust and operational methodology are obvious. On one side we have a large amount of national survey data, probably millions of soil profiles; on other side we have a toolbox of mainly experimental pedometric techniques. If we successfully combine the two, we will be able to significantly improve both semantic and spatial detail of existing soil maps, without re-doing extensive national surveys.

These preliminary results with mapping soil variables for the Danube watershed encourage us to obtain the remaining profile datasets and invest in preparing all possible auxiliary layers that can be used to explain distribution of soil variables. We will also need to consider a number of additional aspects:

**Data quality –** the density of profiles per country is rather inconsistent (Table XIII.1), which could have several negative effects on the model outputs. In addition, several countries have delivered their profiles with unknown spatial reference (we assumed it is related to the WGS84 ellipsoid) or rounded to 2 decimal places of geographical degrees (±1-2 km). Although the regression-kriging can give predictions for any point-data, the final results can be also rather inconsistent and poor (high uncertainty of the prediction model). Still, the advantage of DSM approach to soil mapping is that, once the model is prepared (inputs, outputs, parameters), it only need to be updated with new or corrected profiles to produce the improved maps. A serious question is weather the soil data from different EU countries can be integrated and improved at all? We definitively hope to find some kind of compromise between the data quality, accessibility and coverage. If this will finish in a dead-end street, than we would also recommend new inventories of soil properties over the whole continent (e.g. FOREST FOCUS).

**Computational efficiency –** at the moment, there are only three packages (GSTAT, ISATIS and SAGA) at the market that implement regression-kriging. Since ISATIS allows use of only few predictors, serious interpolation can only be run in

GSTAT. However, even the GSTAT does not implementing the optimal procedure and the calculations can be very time-consuming for dataset consisting of 10,000 of profiles and with many predictors or often impossible (singular matrix problem). Parallel to the development of the interpolation models (fitted interpolation parameters such as regression models and variogram parameters), we will also consider implementation of regression-kriging in the software package SAGA (alternatives are GRASS GIS, R). There have been already some contacts in this direction.

**Accessibility and complexity** – because the geostatistical concepts and procedures are rather complicated, we also need to consider ways to popularize these concepts and make the products more user-friendly. For example, regression-kriging is rather complex technique and it might take time until the traditional soil scientists and similar SIS users accept it. The derived maps of soil properties will be available as raster images with both GIF previews and metadata description. Such layers should be available accessible via a web-applications that allows fast browsing and reading of the data. For this purpose we might need to hire a professional web-programming agency that will be able to implement this functionality.

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# XIV. Topographic data for Digital Soil Mapping applications in Croatia

Martina Baučić

GEOdata d.o.o.
Kopilica 62, 21000 Split, Croatia
Tel.: + 385 21 490497; Fax: + 385 21 490497
martina.baucic@geodata.hr

**Summary**

*Digital soil mapping applications use topographic data as quantifiable element for analysis. Thus, it is important to consider mapping as controlled process resulting with topographic data of known accuracy and generalization. Errors of measurements and their propagation, geodetic reference systems, map projections and topographic modeling are fundamentals of mapping. Topographic data acquisition methods have evolved from tedious and expensive land surveying to digital photogrammetry with fully automated Digital Elevation Model (DEM) and orthophoto production, while GPS enables mapping to everyone, everywhere in any time, with simple and cheap equipment. More powerful and affordable hardware and software enable topographic data processing so, various derived products became available (slope and aspect maps for the analyses, hill shading for visualizations, etc).The most interesting digital product for digital soil mapping is DEM. Again, DEM must meet expected accuracy and it is necessary that input data is of known accuracy (often contour lines from analog maps). In context of all the institutional, technological and business changes, topographic data products in Croatia are evolving too. The new reference systems and map projections have been recently introduced, availability, prices and order forms for the official data can be gathered by web, and on-going projects are aiming towards web dissemination of topographic data.*

## XIV.1 Fundamentals of mapping

Digital soil mapping applications use topographic data as basic input for analysis. Thus, it is important to consider mapping as controlled process resulting with topographic data of known accuracy and generalization. Errors of measurements and their propagation, geodetic reference systems, map projections and topographic modeling are fundamentals of mapping. Mapping encompasses controlled processes and procedures resulting with: the spatial data of known accuracy and generalization, both accordingly to the requested use; e.g. mapping for the road reconstruction results in topography data showing a road corridor with elevation points defining the profiles every 20 m, and with accuracy of ±4 cm. There are fundaments of mapping that must be established far before the process of "*drawing the map*" starts. These are briefly explained in the following paragraphs.

### *XIV.1.1 Measurements*

Primary, mapping is the process of measuring and every measurement is burdened with some error. To know and understand the quality of measured data, there is a need to control errors in the measurement processes. The Theory of Errors explains the nature of errors and their propagation and gives us the statistical models for adjustments of the measurements.

An error can be of gross type and it is easily detected because of its big value and later taken out from further processing. Systematic errors are usually of same amount and with same sign (+,-) and they are mostly caused by instruments or applied procedures. Regular checking of the instruments and use of standard procedures will help in avoiding systematic errors. Random errors are caused by various unknown sources, but they behave accordingly to statistical models and therefore can be taken out by applying adjustment methods.

The main principle is to do multiple measurements of the same feature. The multiple measurements can be of same accuracy or various accuracies considered as weights. Considering that measurements are burdened only with random errors, the most probable value of measured feature is the one with minimum sum of square deviations. In case of so called direct measurements (where the feature can be measured directly e.g. distance measured by meter), the most probable value is the arithmetic mean of all measured values. In case where a value is calculated based on the measurements of other features, the most probable value is calculated by resolving a set of equations. There are two cases: the independent and dependant measurements (e.g. angles in triangle must have sum of 180). The accuracy of the most probable value is given by mean error.

### *XIV.1.2 Reference systems*

The starting point for defining of any feature's position in relation to Earth is to define physical and mathematical models consisting of figures of Earth and coordinate systems, so called Reference systems. Geoid and ellipsoids are models of Earth surface, and geodetic datums, either local or global, horizontal or vertical, are definitions of 3D coordinate systems.

**Geoid** is physically defined figure, described by infinite number of parameters and can be measured by instruments. It can be conceived as the surface of mean sea level extended below continents. **Ellipsoid** is mathematically defined figure, described by two parameters and it is simple geometric surface used as an approximation of geoid to support simpler calculations (Fig. XIV.1).

**Geodetic datum** is set of parameters defining 3D coordinate system in relation to Earth (position of center, scale and orientation) and it includes definition of the ellipsoid. Many different local geodetic datums are in use and they fit geoid the best for the area of certain country or region.

The most known global reference systems are:

- WGS84 which is world-wide used by GPS and based on WGS84 ellipsoid, and
- ETRS89 which is Europe-wide used and based on GRS80 ellipsoid.

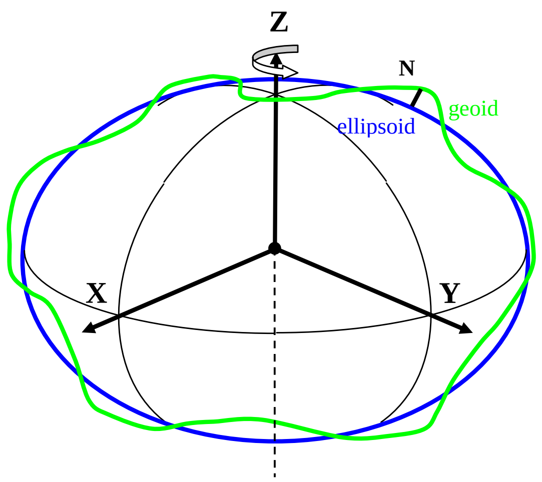


**Fig. XIV.1. Goid, ellipsoid and 3D coordinate system, N is ellipsoid to geoid separation.**

Vertical datum defines the system for measurements of heights (elevations). Traditionally, heights are measured from the geoid surface which has 0 height. GPS heights are measured from ellipsoid surface and to get heights from geoid the value N must be known which varies from point to point (ellipsoid to geoid separation in given point, see Fig. XIV.1). Previously explained reference systems define ellipsoids and their positions in relation to Earth. To use such reference systems for the measuring on Earth's surface, a network of reference points with known coordinates has to be established – the **Terrestrial Reference Frame** (TRF). These reference points are materialized by permanent benchmarks on Earth's surface (e.g. triangulation points belonging to the national triangular networks) and they are used for positioning of unknown points by surveyors. The GPS satellites represent specific TRF points – with known coordinates that changes in time.

### *XIV.1.3 Map projections*

Further simplification of Earth's surface is to model it with a plane. To do so, the relationship between coordinates on the ellipsoid surface and plane must be established. Map projections enable calculation of planar coordinates ($x$,$y$) from the ellipsoidal coordinates ($X$,$Y$,$Z$) or ($\varphi$,$\lambda$,$h$) and vice versa by the use of cartographic equitations, and further more, calculation and control of distortions. Every planar model of Earth contains distortions in shapes, areas, distances or directions.

Map projections vary based on the type of projection surface (cone, cylinder, plane), what distortions are minimized (local shapes – conformal, area – equal area, certain distances – equidistant), and mathematical parameters (e.g. false easting and northing, scale factor, central meridian, longitude and latitude of origin, standard parallels etc). Choice of map projection and its parameters is based on the specific purpose. The chosen map projection should enable measuring distances and angles by applying planar formulas and with adequate accuracy (keeping distortions in defined intervals). Instead of *x* and *y*, the new established standard ISO 19111[11] recommends new labels for planar coordinates: *N* (northing) and *E* (easting).

### *XIV.1.4 Topography modeling*

Topographic data represents Earth's surface depicting natural and built up features, elevations, administration borders and their names. Topographic features have to be generalized and correspondingly represented by various digital spatial data models and types as shown in Fig. XIV.1.

**Table XIV.1. Topographic features types and digital data models.**

| *Type of topographic features* | *Examples* | *Spatial data type* | *Spatial data model* |
|---|---|---|---|
| Discrete objects | utility poles, buildings, peaks | points | vector |
| | streams, roads | lines | vector |
| | countries, land use, buildings | polygons | vector |
| Continuous objects | elevations, temperatures, population density, noise level | triangulated irregular network (TIN) | vector |
| | | grid | raster |
| Spatial relationships | road network, water stream network | logical network (nodes and links) | vector graph |
| | parcels | planar topology (non overlapping polygons filling the area) | |

No one spatial data model or type is a superior one. The context of the problems to be solved should guide which model is the best. Choosing a model will often take into considerations: data availability, required precision, type of analysis and maps to be produced, spatial relationships needed etc.

## XIV.2 Topographic data acquisition methods

Topographic data acquisition methods have developed from sketching simple maps, via surveying by plane table for the systematic national mapping starting in 18th century till today digital techniques that integrate various devices such as GPS and which are used for the global (worldwide) mapping.

### *XIV.2.1 Land surveying*

Land surveying is based on geodetic infrastructure called TRF consisting of permanent benchmarks which compose geodetic control networks. There are horizontal and vertical geodetic control networks. Horizontal control points are located by triangulation and traversing and they are separated in network levels based on accuracy of their (*x*,*y*) coordinates. The elevation of vertical control points is determined by differential leveling and they are also separated in network levels based on the precision standards.

Once the **geodetic networks** are established, surveyors access and observe known and unknown points with the surveying instruments (total stations, levels) and calculate position of unknown points. Point by point, topography features are calculated and mapped. The highest accuracy could be achieved (in mm), depending on used instruments, applied surveying methods, and the accuracy of geodetic control network used (e.g. control points are from the high accuracy local control network without fitting to the less accurate national geodetic network). Land surveying is mostly used as topographic data acquisition method for small areas and when the required accuracy is high (e.g. design and construction of roads and buildings).

[11] This ISO guide can be obtained from [www.iso.ch]; see also the Open Geospatial Consortium at [www.opengeospatial.org].

### *XIV.2.2 Global positioning system*

Basically, Global Positioning System (GPS) is type of land surveying based on distance measuring. The GPS reference frame is made of the satellites with known coordinates in any moment. Surveyor observes satellites from an unknown point by GPS device, measures distances towards the observed satellites and calculates position of the unknown point. GPS has assured the following:

- positioning of any point worldwide;
- at any time (24 hours, 356 days);
- in real time (it enables tracking);
- in one world reference system;
- without expert knowledge;
- with cheap equipment;

GPS can produce data of the highest accuracy (mm). The raw GPS data is in WGS84 reference system what means that heights are ellipsoidal ones. Water modeling needs heights measured from geoid surface what should be taken into consideration when raw GPS data is collected. GPS has revolutionized surveying. Today, everyone is mapping in real time by simple use of one handheld device which integrates GSM, GPS and PC, and with price less then 1000 €.

### *XIV.2.3 Photogrammetry*

Topographic data can be acquired from photographs by stereoscopic vision. Two images of the same area but taken from different perspectives are used for recreation of three dimensional space. Three dimensional topographic data is mapped by applying photogrammetric techniques of interior and exterior orientations of the photographs, relative and absolute model orientations, and by stereo plotting which measures parallaxes and thus elevations. Introduction of aerial triangulation and bundle block adjustment techniques has significantly improved photogrammetry and therefore photogrammetry has become the most used data acquisition method for national mapping (fast data acquisition covering large areas with medium accuracy from cm to dm).

Today, photogrammetry goes digital: from digital cameras to digital processing and mapping. Digital cameras acquire multispectral data of high ground resolution; digital processing automates orientation, generation of digital terrain models (autocorrelation techniques) and ortophoto production; stereomapping is achieved by either anaglyph or polarization techniques. Digital photogrammetry asks for huge hardware and software resources because huge data volumes have to be processes and stored (one standard 23×23 cm color aerial photo in digital format has approximately 1 GB).

### *XIV.2.4 Lidar, radar, remote sensing*

Lidar (**Light detection and ranging**) is data acquisition technique that integrates laser (active sensor), GPS and INS (inertial navigation system) mounted on aircraft. For the topography mapping purposes Lidar has several advantages and disadvantages: fast data capture of many sample points, good vertical accuracy (15 cm) but weak horizontal (50–100 cm), it is not suitable for steep areas and it does not penetrate rain and smoke, lots of filtering is still needed (e.g. filtering out vegetation) and often manual filtering. Equipment is still quite expensive, but new developments are going on and certainly Lidar has future for topographic mapping.

Radar (**Radio detection and ranging**) emits microwave signals and measures their reflectance off objects. Radar is mounted on aircraft or satellite. For the topographic mapping purposes, Radar has its advantages and disadvantages: high accuracy of elevation (from cm), but weak horizontal accuracy (starting from 1 m), fast data capture suitable for large areas, it penetrates rain and smoke.

SRTM (**Space Shuttle Radar Topographic Mapping**) mission from 2000 has resulted in 80% world coverage of radar images which were taken by interferometric synthetic aperture radar (Fig. XIV.2). As two images were taken in the same time from two radar's antennas, the three dimensional data was derived. Vertical accuracy is approximately 16 m, horizontal accuracy is given by pixel size of 30/90 m. Remote sensing uses multispectral sensors mounted on satellites. For topographic data acquisition of large areas, SPOT stereo pairs can be used (pixel size is 30 m and vertical accuracy is 10 m).

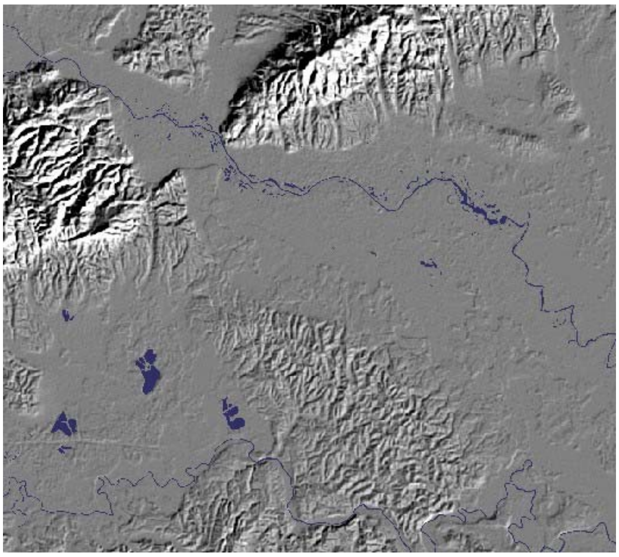

**Fig. XIV.2. The DEM of Croatia at resolution of 100 m produced by merging the DEM from the topo maps and the SRTM DEM. The block shows area around city of Zagreb.**

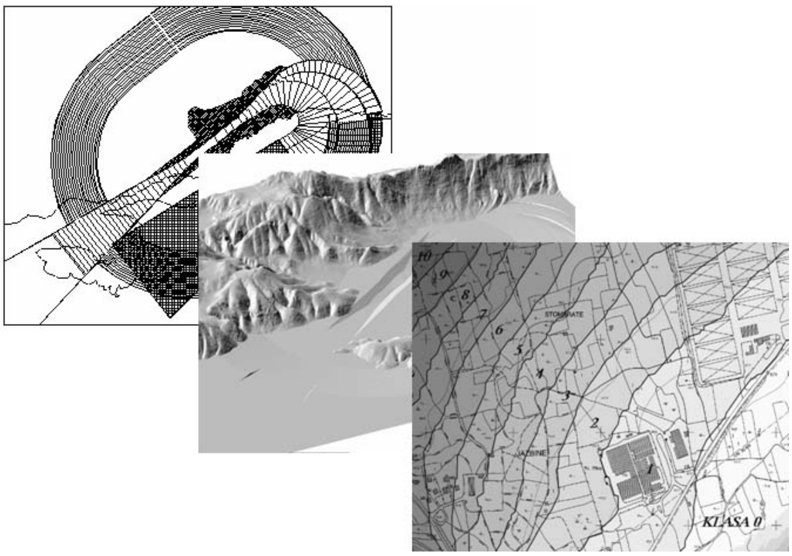


**Fig. XIV.3. 3D spatial analysis products: modeling surfaces for aircraft operations; overlay with terrain, classification based on distances from terrain to aircraft operations surface.**

## XIV.3 Digital topographic data products

### *XIV.3.1 Raw and derived products*

The results from topographic data acquistion can be delivered as raw data or can be further processed and shaped into various products. Regularly, the topographic data is delivered as follows:

- list of coordinates
- digital maps (vector or raster)
- orthophotos
- topographic databases
- digital terrain models (DEM) and derived products (slope and aspect maps, hill shading)
- visualizations.

### XIV.3.2 Digital Elevation Models

Traditionally, Earth's surface was represented with contour lines. Today, Digital Elevation Models (DEM) can be: (a) Raster models (grids) and (b) Vector models – triangulated irregular networks (TIN). The main idea behind any model is to collect few data on field, and to interpolate all other data by model. DEM is derived from raw data with known ($x$,$y$,$z$) and it enables us to get $z$ (elevation) for any point given with ($x$,$y$). DEM must satisfy certain purpose what places certain accuracy requirements ($z$ derived by interpolation must lie within expected accuracy of the model). Input data for the generation of DEM is classified into:

- characteristic terrain points (e.g. peaks)
- break lines (e.g. dam edges)
- exclusion areas (e.g. lakes)
- project boundaries (in case of volume calculations).

Till today, one of the most common data source for DEM generation was contour lines and height points from existing analog maps.

### XIV.3.3 Map accuracy

To calculate accuracy of DEM one should first calculate accuracy of input data. Then, by implementing error propagation theory, the accuracy of interpolated elevations can be calculated too. General rule tells that data on analog maps has positional ($x$,$y$) accuracy described by mean error which can be calculated by:

$$\mathrm{m} = \pm\ 0{,}2\ \mathrm{mm} \cdot \textit{scale factor} \qquad (1)$$

where:

$m$ – stands for mean error of position drawn on the map ($x$,$y$).

Accuracy of the relief representation by contour lines is given by Koope's formula:

$$m_H = \pm\left[A + B\cdot\tan(\alpha)\right] \qquad (2)$$

where:

$m_H$ – stands for mean error of any point height calculated by linear interpretation from contour lines,
$A$ – is height error caused by collection of elevation data,
$B\cdot\tan(\alpha)$ – is height error caused by horizontal position error of collected data,
$\alpha$ – is angle of terrain slope at the point.

### XIV.3.4 Croatian topographic map 1:25,000

Positional accuracy of the Croatian topographic map 1:25,000 is:

$$m_{TK25} = \pm\ 0{,}2\ \mathrm{mm} \cdot 25000 = \pm\ 5\ \mathrm{m} \qquad (3)$$

where:

$m_{TK25}$ – stands for mean error of position ($x$,$y$) drawn on the Croatian topographic map scale 1:25,000.

Accuracy of the relief representation by contour lines is given by Koope's formula, and according to M. Peterca (1974), and for the terrain with medium heights:

$$m_H = \pm\ \left[1.4 + 5.6\cdot\tan(\alpha)\right] \qquad (4)$$

where:

$m_H$ – stands for mean error of any point height calculated by linear interpretation from contour lines,
$\alpha$ – is angle of terrain slope at the point;

and for point at slope of 7.6°:

$$m_H = \pm\left[1.4 + 5.6 \cdot \tan(7.6^\circ)\right] = \pm 2.2 \text{ m} \qquad (5)$$

### *XIV.3.5 Croatian base map 1:5,000*

Positional accuracy of the Croatian base map 1:5,000 is:

$$m_{HOK5} = \pm 0.2 \text{ mm} \cdot 5000 = \pm 1 \text{ m} \qquad (6)$$

where:

$m_{HOK5}$ – stands for mean error of position ($x$,$y$) drawn on the Croatian base map scale 1:5,000.

Accuracy of the relief representation by contour lines is given by Koope’s formula, and according to P. Lovrić (1988):

$$m_H = \pm\left[0.25 + 2.5 \cdot \tan(\alpha)\right] \qquad (7)$$

where:

$m_H$ – stands for mean error of any point height calculated by linear interpretation from contour lines,
$\alpha$ – is angle of terrain slope at the point;

and for point at slope of 7.6°:

$$m_H = \pm\left[0.25 + 2.5 \cdot \tan(7.6^\circ)\right] = \pm 0.6 \text{ m} \qquad (8)$$

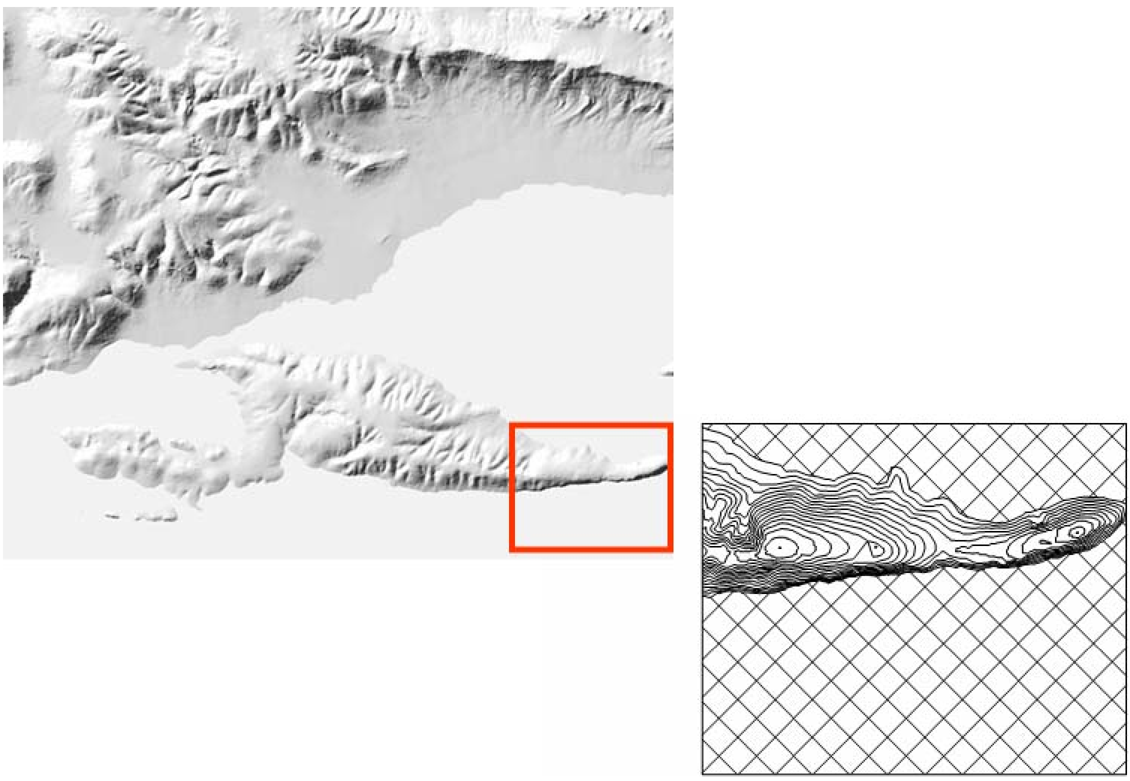

**Fig. XIV.4. Hill shading produced from DEM. DEM was made based on elevation data (elevation lines with equidistance of 10 m and elevation peaks) digitized from Croatian topographic maps in scale 1:25,000.**

## XIV.4 Topographic data products in Croatia

Topographic data products in Croatia have their origin in State Geodetic Administration (official and standardized topographic data), public companies and institutions for natural resources and utilities (specific topographic data for their use), and in private companies which are primary producer of topographic data. System of licensing defines that licensed surveyors and companies have exclusive rights to produce official topographic and cadastral data for various purposes (for civil engineering, urban planning etc).

### *XIV.4.1 Croatian reference systems and map projections*

In 2004 Croatia has introduced the new official reference systems and map projections (by government decision based on the Law on state survey and real estate cadastre). Also, the Programme for introduction of the new systems has been made.

The new official **Croatian horizontal datum** has the following specifications:

- European Terrestrial Reference System per epoch 1989 (ETRS89)
- ellipsoid GRS80 ( a = 6378137,00 m, m = 1/298,257222101)
- positional network consisting of 78 geodetic base points which are permanently benchmarked and which coordinates are defined in ETRS89, is base of horizontal reference coordinate system of Republic of Croatia
- positional reference coordinate system of Republic of Croatia in which 78 geodetic base points coordinates are defined in 1996 will have a name – Croatian terrestrial reference system per epoch 1995.55 or HTRS96.

The new official **Croatian vertical datum** has the following specifications:

- geoid surface which is defined by mean sea level on the mareographs in Dubrovnik, Split, Bakar, Rovinj and Kopar in epoch 1971.5 is reference surface for the calculation of heights in Republic of Croatia
- heights network which is made of permanently benchmarked “repers” of II order high accuracy leveling which heights are defined in system (normal) of earth gravity field, is base for vertical reference system of Republic of Croatia
- vertical reference system of Republic of Croatia defined on base of mean sea level has name – Croatian vertical reference system per epoch 1971.5 – HVRS71.

The new official **Croatian map projections** are defined as follows:

- Transverse Mercator projections (Gauss-Krüger) – HTRS96/TM, central meridian 16°30’ and linear scale on central meridian 0,9999 (for cadastre and detailed state topographic cartography)
- Lambert conform cone projection – HTRS96/LCC, standard parallels 43°05’ and 45°55’ (for overview state cartography).

### *XIV.4.2 Croatian State Geodetic Administration data products*

Official topographic and cadastral data in Croatia is provided by State Geodetic Administration (SGA). SGA is in charge of collecting, processing and delivering of spatial data. In addition, SGA is preparing laws and regulations and technical standards. Primary producers off all topographic data are licensed private companies contracted by SGA for the topographic data production. For more details about SGA activities, products, price lists, order forms and data availability see [www.dgu.hr].

The basics of technical standards are defined in “Rulebook for topographic survey and production of official maps”. Some recently established standards concerning topographic data are the following:

- quality control is provided by Croatian Geodetic Institute or contractors
- aerial photos in scale not smaller then 1:20,000 are taken in interval of 5 years and they serve as a base for maintaining maps and databases (1:5000, 1:10,000, 1:25,000)
- accuracy of data collected by photogrammetry for topographic database and map 1:25,000, represented by mean error, should be less then:

  ± 1m for built and well defined objects, and
  ± 3m for natural and not exactly defined objects.

- DEM maximal allowed error is:

  ± 1.5 m for DEM based on 1:5,000 map scale, and
  ± 3 m for DEM based on 1:25,000.

**Table XIV.2. Selected Croatian State Geodetic Administration data products and orientation prices.**

| *Data product* | *Price* |
|---|---|
| Geodetic control points | 10 – 20 HRK per point |
| Aero photos (digital/analog, color/BW) | 50 – 1500 HRK |
| Digital orthophotos | 450 – 800 HRK /map sheet |
| Croatian base map 1:5000 analog | 50 – 130 HRK / map sheet |
| Croatian base map 1:5000 georeferenced raster | 220 HRK / map sheet |
| Topographic maps 25, 50, 100, 200 analog | 15 – 200 HRK / map sheet |
| Topographic maps 25, 50, 100, 200 georeferenced raster | 500 HRK / map sheet |
| Topographic maps 25, 50, 100, 200 (> 1997) | 700 HRK / map sheet |
| Database of spatial units, various excerpts | 5 – 5,000 HRK |
| DEM 1:25,000 | 2000 HRK / map sheet |
| DEM 1:25,000 with mash | 5000 HRK / map sheet |
| DEM 1:5,000 | 250 HRK / map sheet |
| DEM 1:5,000 with mash | 700 HRK / map sheet |
| Digital vector map of Croatia 1:300,000 | 10,000 HRK |
| Cadastral maps analog/ georeferenced raster | 30–300 HRK / map sheet |

Besides topographic data mapping, some of the on-going SGA projects are:

- development of national spatial data infrastructure
- establishment of topographic databases and web dissemination of data
- establishment of central cadastral database
- new cadastral surveys.

## XIV.5 Conclusion

World of topographic mapping is rapidly changing: from the producers who are not exclusively surveyors, till the users who are not using topography only as colourful backdrop image. Creation of digital topographic databases covering large areas and more widely available hardware and software for the spatial data processing have resulted in new ways of data usage, what again has resulted in new requirements on topographic data.

Smith (2005) believes that "*Topographic data is not only interesting backdrop for soil mapping but an actual layer and quantifiable element for analysis*". Digital soil mapping asks for more and more topographic features and their parameters to be measured, also it asks for repetitive measurements so dynamic processes can be modeled. Therefore, it is necessary to consider digital soil mapping requirements for design of future topographic databases and to review them on regular basis.

This report shows that there are large amount of high quality base data that can be used to support digital soil mapping projects. Their price is continuously dropping with an increasing availability of new technologies. The basic topographic data, collected by the national geodetic department, can also be supplemented with remote sensing imagery and similar products from the international agencies and companies. Today, we need to focus more on proper use of the topographic data for mapping applications, instead of questioning its availability.

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# XV. Methods for creating Functional Soil Databases and applying Digital Soil Mapping with SAGA GIS

Michael Bock[1,2], Jürgen Böhner[2], Olaf Conrad[2], Rüdiger Köthe[1] and Andre Ringeler[1,2]

1 Scilands GmbH – scientific landscapes
Goetheallee 11, D-37073 Göttingen, Germany
Tel.: + 49 0551 5315870; Fax: + 49 0551 5315873
mbock@scilands.de; koethe@scilands.de

2 University of Hamburg, Section for Geography,
Bundesstraße 55 (Geomaticum), D-20146 Hamburg, Germany
Tel.: + 49-40-428384960; Fax: +49-40-428384981
boehner@geowiss.uni-hamburg.de; conrad@geowiss.uni-hamburg.de;
ringeler@geowiss.uni-hamburg.de

## XV.1 Introduction

Digital Soil Mapping (DSM), as a comparatively new buzzword within soil sciences, integrates different procedures of providing soil relevant digital data. It offers solutions for a *growing demand for high resolution soil maps world-wide* (Behrens & Scholten 2006). The driving force behind DSM is the need – mostly out of financial reasons – to keep the portion of field and laboratory work when generating spatial valid soil data as small and as effective as possible. This need is now combined with the possibilities being offered by spatial modelling and modern GIS analysis.

Within the last years, the working group geosystemanalysis (**Section for Physical Geography**, University of Hamburg, former university of Göttingen) and **Scilands GmbH** (Göttingen) have been developing several independent approaches to assist the soil mapping process with automated procedures. A concept of Geomorphographic Maps (GMK) – entities with homogeneous conditions regarding the terrain, which is completely scale independent and suitable for countrywide surveys – was developed. A methodological framework for the spatial prediction of the distribution of soil characteristics with the help of enhanced terrain parameters, so-called process parameters, was further prepared to be used for medium and large scale studies. In contrast to conventional classifying mapping strategies, soil characteristics are interpreted functionally as various continuous metric values. Different procedures – statistical, geostatistical and combined – to generate these metric soil data were tested and developed further to answer the question under which circumstances the particular procedures can reveal their strengths. These methods require Europe-wide available homogenous data, e.g. digital elevation models, climate modelling data, metric data of soil characteristics derived from soil profiles, remote sensing data, etc. and the local knowledge of regional soil and landscape genesis.

The research done previously by the same group aimed at production of a software packages for an automated analysis of **Digital Elevation Models** (DEM) that will be superior to common GIS tools in this particular field. The goal of these software tools was to assist the soil mapping process in Germany for large scale soil maps as well as for the area of the whole country. The final output of our collection of procedures and methods was a GIS package named **System for Automated Geoscientific Analyses** or SAGA. The working group decided to develop an own GIS system because the deficiencies of the conventional GIS commonly used in geosciences at that time. The need for a powerful and flexible tool that gives a researcher the freedom of creating his scientific methods as software modules made that decision even easier. After years of development SAGA – now in the version 2.0 – has become a comprehensive tool with increasing community of users and developers.

The working group can now benefit from extensive experiences of research projects and software developing. What is still missing in this system, at present, is integration of different DSM approaches. In the following sections, individual elements of the DSM framework are mentioned and the way to combine them as compartments that build on each other is described.

### *XV.1.1 Availability of necessary data sources*

The European Soil Bureau Network aims to collect soil data of the member states and to produce a harmonized European soil database at a more detailed scale than the existing 1:1,000,000 map. Below we estimate the availability of some necessary data that should flow into such a soil map with a focus on information about the terrain. This enterprise – *harmonisation of the European soil data* – executing simply for soil profile data is the subject-matter of autonomous and long-lasting research projects such as SPADE1 and SPADE2. For further information we refer to the corresponding publications (Hollis et al 2006). We start our examinations from the point of existing harmonised metric data values for soil parameters at point observations.

Things are simpler if we look at the data situation concerning DEM. Since the year 2000 there has been a totally new situation concerning Europe wide DEM due to the Shuttle Radar Topography Mission (SRTM). A consortium of NASA and European partner agencies collected surface specific data of nearly the whole planet – between 60 degrees north and 60 degrees south – using the RADAR interferometry. Fig. XV.1 shows the SRTM data availability for the European continent. Since then, everyone has been able to make use of this free data. However, there are still many aspects concerning the data quality that need to be considered:

**The resolution of the data is 3 arc seconds**. This means that every calculated grid size under about 75 meters is just blowing up of the amount of data. Morphological phenomena of smaller dimension cannot be represented in SRTM data.

**The data gaps that occurred when influences of water, dust or ice in the atmosphere disturbed the RADAR signal have to be closed**. In most cases the gaps are small (only a few grid cells) so closing these gaps is no problem for a popular interpolation method like e.g. inverse distance. Sometimes it happens that the gaps are bigger. Then a morphological interpolation method, e.g. the one JARVIS et al published in 2004, has to be used. In most cases satisfying results can be achieved but certainly there are limits filling the gaps without additional data.

**The DEM values have to be preprocessed to get a hydrologically correct DEM**. Special filter techniques have to be applied to eliminate what Selige *et al.* (2006) call the *mulehill phenomena* as well as the thermal noise that is immanent in SRTM data. The working group geosystemanalysis, for example, uses algorithms to keep the details of existing terrain features while eliminating the disturbing noise (Köthe & Bock 2006).

**SRTM data is a Digital Surface Model representing the vegetation surface and is not a DEM**. So forest areas in flat regions like for example in Poland, the northern part of Germany, the Netherlands or big river valleys like the Rhine, the Po or the Danube are represented in the data. However, for soil science analysis a clear model of the surface of the ground is needed. Therefore, the existence of forest areas must lead to errors in the terrain analysis. An automatic detection and correction of forest areas out the data itself is not possible due to the smoothed appearance of the edges that could appear similar to the edges of natural forms of the terrain. Our experience is that use of the homogeneous Europe wide data set CORINE land cover to filter the natural and artificial objects can lead to satisfying results, as illustrated in Fig. XV.2.

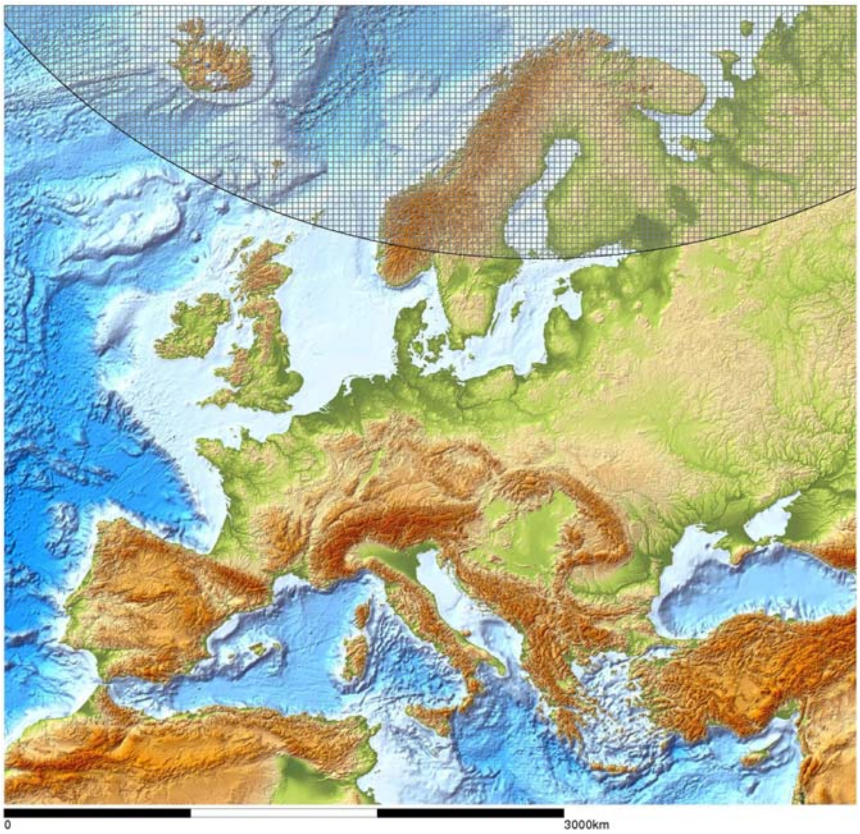


**Fig. XV.1. Availability of SRTM data in Europe. The area hatched in grey colour is north of 60° degree latitude and therefore not available. The presentation of the continental area in this figure is based on SRTM data and was generated with SAGA GIS.**

**Geological maps** can give important hints about the parent material of soil genesis. The problem is that one cannot expect to get homogeneous data sets concerning the scale of the underlying map when different countries are participating. The case study of Nilson et al. (2006), illustrates inconsistencies of geological GIS data for environmental studies in an area of three neighbouring member states of the European Union (Belgium, the Netherlands and Germany). It will make a difference whether the digitized geological map is at scale of 1:25,000 or 1:100,000. Further problems occur concerning the different national geological systems. The geological strata often are assigned to national bio- and lithostratigraphies, which do not fit in detail. Nilson et al. (2006) concluded that "*fundamental inconsistencies can not be handled by data management strategies. Here, co-operation networks like the International Commission on Stratigraphy (ICS) have to be involved and new surveys may be necessary*". At present, such characteristics of this important information layer do not make it possible to use the geometric properties of these data sets. The only way to integrate the information are either by handling the polygons of the geologic vector data as process areas as shown below or by using them for further interpretation of the entities of the geomorphographic data as the result of the terrain analysis process.

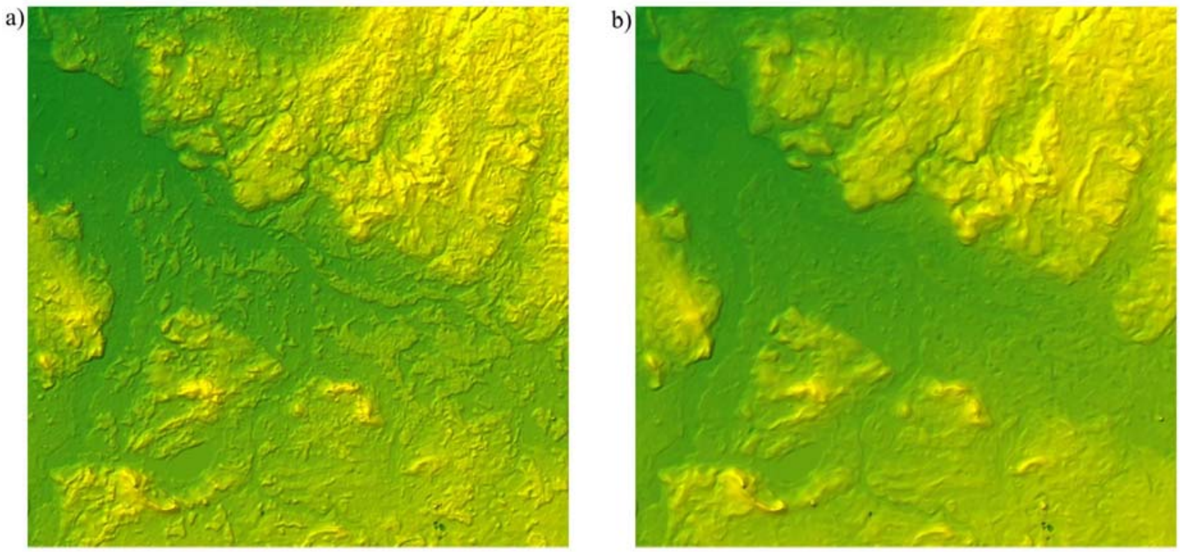


**Fig. XV.2. Elimination of forest areas in SRTM data in flat regions. A part of northern Germany (about 50×50 km) in (a) unprocessed version and (b) after eliminating the forest areas and adjustment of the values with the help of CORINE landcover data.**

## XV.2 SAGA GIS as a comprehensive tool for Digital Soil Mapping

Since the 2001, the GIS software SAGA has been developed by the members of working group geosystem analysis with the aim to facilitate the processing of spatial data. Because our research depends, to a far extent, on the creation of new innovative methods, the Application Programming Interface (API) of SAGA became a central role in the system's development. Many functions of the API have been specially tailored to fit our needs in data processing as well as to overcome restrictions, which we experienced with other software solutions. The object oriented design of the API, which is completely written in C++, enables an effective access to spatial data, regardless of the raster or vector format. Besides the data access, the API provides also numerous helpful functions, including regression analysis, sorting algorithms and matrix operations. Due to the intuitive and comprehensive API the number of analytical methods implemented under SAGA could rapidly be extended. Under the SAGA environment all methods are wrapped in so called SAGA modules, which in turn are collected in dynamically loadable program libraries. A major advantage of this modularisation is that methods can be developed independently from the system's framework. The execution of SAGA modules is easily done via a graphical user interface, which also is responsible for the management of spatial data and its visualisation. Alternatively modules might be executed from a command shell, through which it is possible to write batch scripts and to combine several calls of modules for a further automation of more complex work flows.

In the 2004, the source code of SAGA framework and a larger number of our SAGA modules have been made publicly available via [www.saga-gis.org]. This was done to call the attention of other research groups and scientific developers to our work. The publication of SAGA as a Free Open Source Software (FOSS) resulted soon in a remarkable feedback. Among the contributions from an evolving world wide SAGA user community are many new modules and, perhaps most notably, a user manual (Olaya 2004), which covers most of SAGA's analytical capabilities. Various enhancements have been applied to the current SAGA version 2, which now runs on Windows as well as on Linux operating systems and allows to use its API with the popular script programming language Python.

The current collection of free SAGA modules reflects first of all our own research activities, which have a strong focus on raster based analyses. Many of the modules have actually no analytical or modelling background, but undertake standard GIS operations, like data format conversions or geographical projections. Tools special to raster data cover amongst others filter algorithms, a flexible calculator, resampling routines and image classifications. Tools for vector data range from the merging and splitting of layers to polygonal intersections. Several further modules are available for geostatistical data analysis and the analysis of digital terrain models. But apart from the modules, which have been published under a FOSS license, we also developed a large number of additional modules. Some of these will be mentioned in the following and many more were used in the background. An overview of current application scopes is given in Böhner et al. (2006).

## XV.3 Process parameterisation and terrain parameters

### *XV.3.1 Process parameterisation*

Since the mature of GIS in the early 1990's, automated terrain analysis evolved to a well established methodical standard in (continuous and discrete) soil spatial prediction applications. Due to the momentum and rapid growth of GIS technologies on the one hand, and the vast amount and eased availability of suitable DEM on the other, the amalgamation of computer-assisted cartography with database technologies in current GIS fostered and effected method development in the field of automated soil mapping. Particularly in rather hilly environments, terrain analysis applications became generally accepted measures to predict the spatial variability of a targeted soil variable by using one or a set of terrain predictors (e.g. Odeh et al. 1995, Knotters et al. 1995). According to McBratney et al. (2003), who analysed peer-reviewed publications on soil regionalisation, 80% of the studies published since 1990 utilised terrain attributes as key predictors.

However, although numerous promising soil mapping approaches had been published so far (McBratney et al. 2003), most of them mainly emphasise on the GIS-based design of environmental correlation and its involved geostatistical and statistical methods. Distinctly less commitments, instead, had been paid towards an evaluation of involved predictor variables, its suitability for automated soil mapping and its causal relation to the desired soil parameters. Indeed, since the pioneering work of Moore et al. (1993), who probably yielded the first automated soil parameter maps (e.g. A-horizon depth, Ph-values) for a small catchment area in Colorado, using both, local and regional terrain parameters, the terrain analysis for soil mapping applications goes seldom beyond standard terrain parameters.

In order to enable a more causal justified soil mapping support under consideration of soil forming processes, Böhner et al. (2002) Böhner & Köthe (2003), Böhner et al. (2003) and Böhner & Selige (2006) proposed new process-based parameters as basic predictors for soil mapping applications. The generic idea of process parameterisation is to extend the predictive capacity of DEM variables twice: firstly by recombining local and regional terrain attributes, and secondly by integrating climate variables, in both cases to better represent soil-relevant processes. The strong emphasis on the process level reflects experiences from numerous research projects on automated soil mapping in different parts of Germany. No matter which kind of statistical or geostatistical methods are used to compute spatial transfer functions, a suitable estimation of soil attributes is only to be achieved, if the soil forming processes itself are properly represented by the predictor variables.

Based on the assumption that the current state of soil development in mountainous environments is a response on Late Quaternary lateral processes, the set of constructed process parameters can be used to represent the terrain-determined overland flow and soil moisture distribution (SAGA Wetness Index), the strength of Late Pleistocene solifluvial processes (Solifluction Parameter) as well as Holocene denudation, erosion and accumulation processes (Sediment Transport Parameter and Mass Balance Parameter). Different from soil mapping approaches, which consider the climate factor by separately defined climofunctions (e.g. Arrouays et al. 1995; Hengl et al. 2002; Ryan et al. 2000; McKenzi & Ryan 1999), we directly integrate those climate variables, which we assume are relevant for the parameterisation of soil related and soil forming processes. The required climate layers are estimated, using a semi-empirical modelling approach. Since spatio-temporal climatic variations are widely controlled by large scale circulation modes (or associated advection processes, respectively) and topographic settings, the climate regionalisation scheme combines statistical downscaling of GCM (General Circulation Model) data and advanced surface parameterisations, to enable a physical consistent dynamical estimation of spatially extended climate variables. Fig. XV.3a shows for example the Potential Solar Radiation. The entire modelling approach was developed and tested on the example of modelling domains in Germany (Böhner 2004), Asia (Böhner 2006) and South America (Conrad et al. 2006), and thus is assumed to enable a methodical consistent and homogenous estimation of soil relevant climate layers for the whole of Europe.

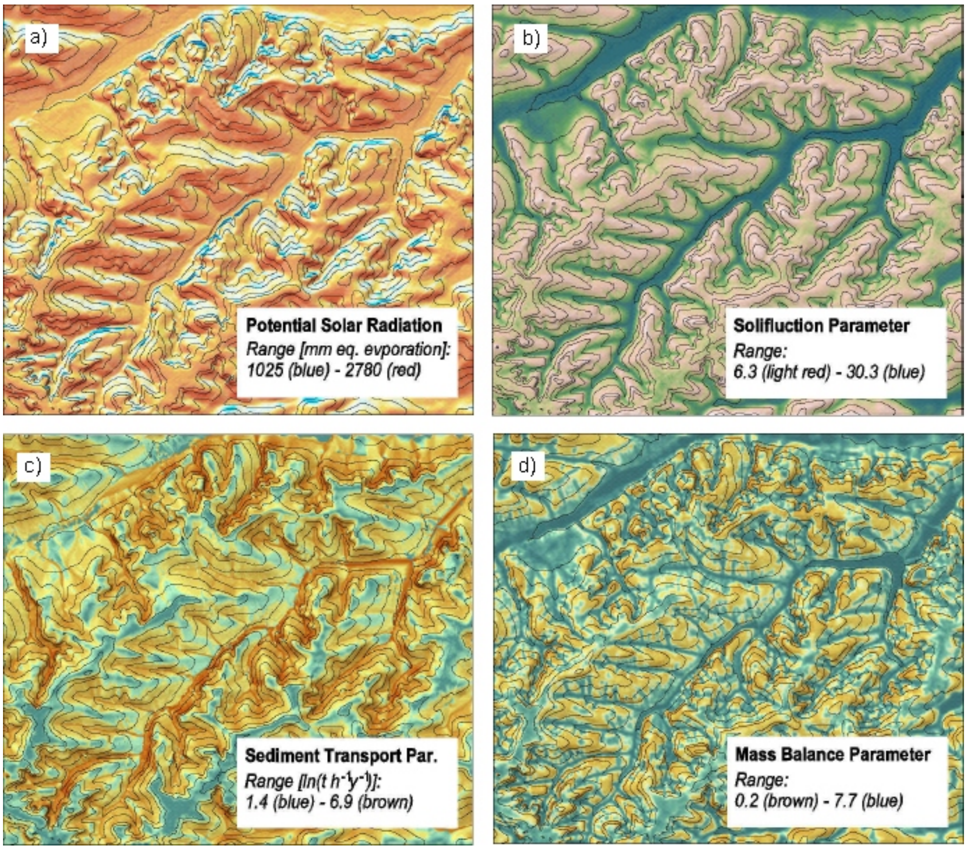


**Fig. XV.3. Examples for complex terrain parameters and process parameterisation: hilly tertiary region of the South German Molasse Basin, 1088×876 grid cells, grid cell size: 5 m.**

### *XV.3.2 Modified complex terrain parameters*

Especially in lowly inclined regions, such as fluvial and glacial formed landscapes, it is sometimes difficult to achieve satisfying information from terrain analysis. To improve terrain parameters for soil regionalisation in these regions and to achieve terrain parameters for the delineating of process areas respectively for terrain classification, modifications and variations of the complex terrain parameters are necessary.

The **modified SAGA Wetness Index** (mSWI) is a modification[12] of the SAGA Wetness Index (SWI), which is derived by weighing (multiplying) the slope angle within the calculation of the index. Fig. XV.4(c,d) shows the "normal" SWI (Fig. XV.4c) and the mSWI by weighing the slope angle with factor 6 (Fig. XV.4d). The mSWI index now shows in the flat northern part of Fig. XV.4d a lot of details, such as holocene and pleistocene flood plains and terraces (blue colours) in contrast to pleistocene moraines and sandy outwash planes (light blue to yellow). Another advantage is the increased contrast between river flood plains and slopes in the southern mountainous region of Fig. XV.4. Big valleys, basins and rifts (blue) contrast with minor valleys (yellow) and slopes (red).

The modifications of A**ltitude Above Channel Lines** and **Altitude Below Ridge Lines** do not consist in modifying the calculation of the indexes but in defining channel lines and ridge lines. The calculations are accomplished by standard SAGA module Vertical Distance to Channel Network whereas for calculating altitude below ridge lines the altitudes of the DEM have to be inverted.

The calculation of **Channel Lines** (stream lines) from DEM is mainly based on the terrain parameters altitude, flow accumulation (using a multiple flow algorithm) and a convergence index. Threshold values for flow accumulation and convergence index are used to define the starting point of a channel line. As the definition of the starting point of a channel line is always subjective, different threshold values and postprocessing steps can produce quite different results. Fig. XV.4a shows two different channel networks: the light blue channel network (1) is much more detailed than the dark blue channel lines (2), which only follow the main valleys with low gradients. The modified complex terrain parameter Altitude Above Channel Lines pre-

[12] Because the modified and combined complex terrain parameters are quite new developments they are up to now not tested for soil regionalisation.

sented in Fig. XV.4b is based on the channel network (2) from Fig. XV.4a that can be now used to improve terrain classification.

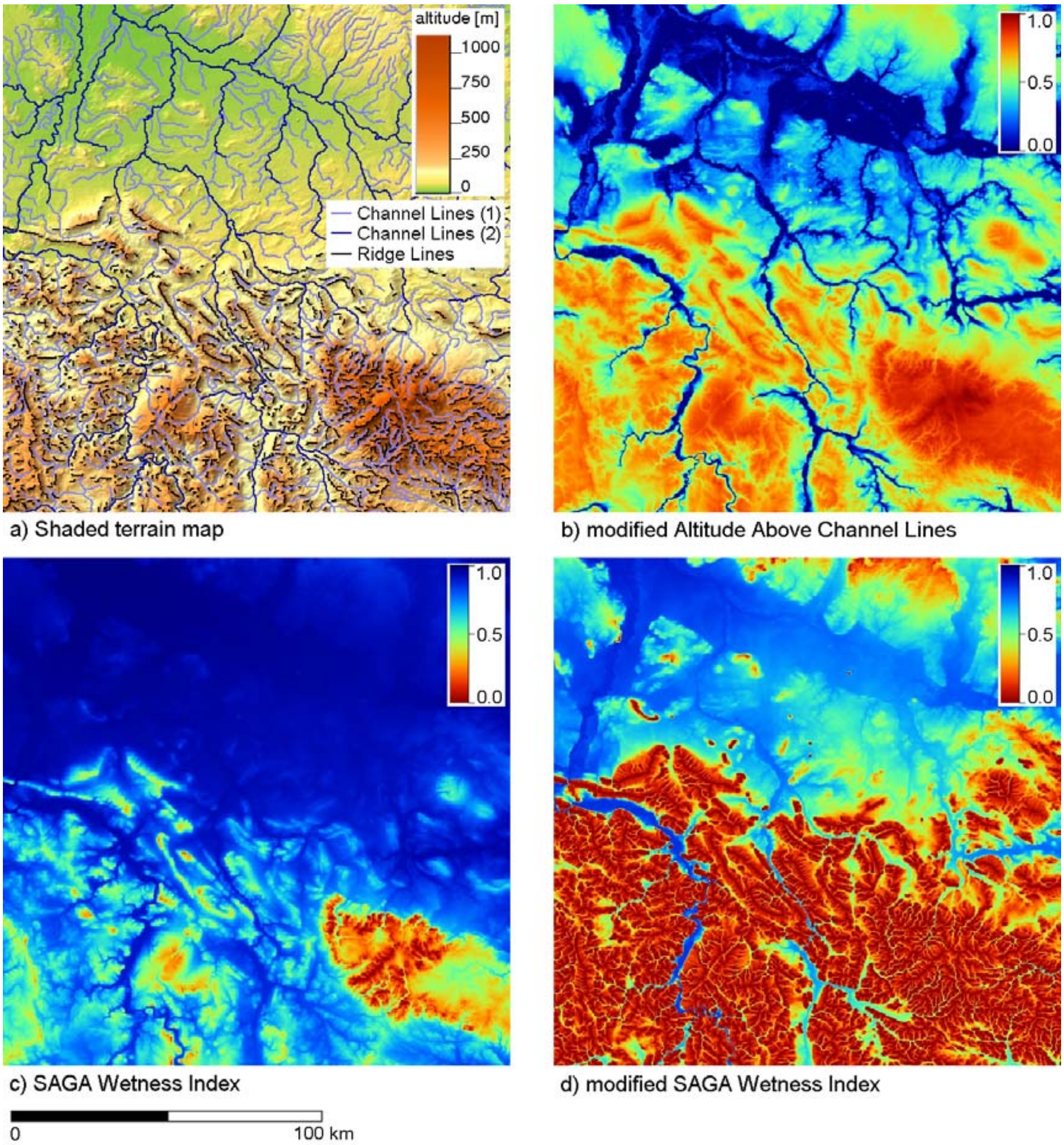


**Fig. XV.4. Examples for modified complex terrain parameters. The sample area covers some typical types of landscape in central Europe: highlands with mesozoic and paleozoic bedrocks in the south, pleistocene terraces, moraines (partly loess covered) and dunes in the north as well as holocene river flood plains.**

**Ridge Lines** are calculated by using threshold for a minimum of the divergence index, for a minimum angle of different aspects of adjacent grid cells and optional for a maximum of (modified) SWI and for a minimum of Altitude Above Channel Lines. The Ridge Lines in Fig. XV.4a match very well the hills and mountains with mesozoic and paleozoic bedrock in the shown area.

### *XV.3.3 Combined complex terrain parameters*

The combination of two or more complex terrain parameters using simple formulas can create new useful terrain parameters. It also helps to simplify complicated interrelations between complex terrain parameters, e.g. for multiple regression analysis. Because the values of the complex terrain parameters vary in ranges, units and frequency scales, it is necessary to standardise the values by pre-processing steps, such as normalisation, inverting, or taking the logarithm.

A very useful combined terrain parameter is the **Relative Slope Position**, a combination of Altitude Above Channel Lines and Altitude Below Ridge Lines using the following formula:

$$AACL / (AACL + ABRL) \quad (1)$$

where

AACL – stands for Altitude Above Channel Lines [m],
ABRL – stands for Altitude Below Ridge Lines [m].

The resulting values range from downslope 0.0 (= channel lines) to upslope 1.0 (= ridge lines). Fig. XV.5a represents the relative slope position based on the Channel Lines (1) and the Ridge Lines presented in Fig. XV.4a.

Another example for combined complex terrain parameters is the combination of **modified SAGA Wetness Index (mSWI)** and **Altitude Above Channel Lines** using a variable formula like:

$$( (2 \times AACL) + mSWI ) / 3 \quad (2)$$

where

AACL – stands for Altitude Above Channel Lines (natural logarithm, normalised) [index 0.0 to 1.0],
mSWI – stands for modified SAGA Wetness Index, (inverted, normalised) [0.0 to 1.0] weighting factor for slope angle (in Fig. XV.5b and 6 = 10).

This combined complex terrain parameter represents several processes which formed morphological terrain features and shows a lot of terrain details particular in low inclined regions. The parameter can be used as a **terrain classification index for lowlands** ($TCI_{low}$), a data set as shown in Fig. XV.5b and suitable for extracting terrain units.

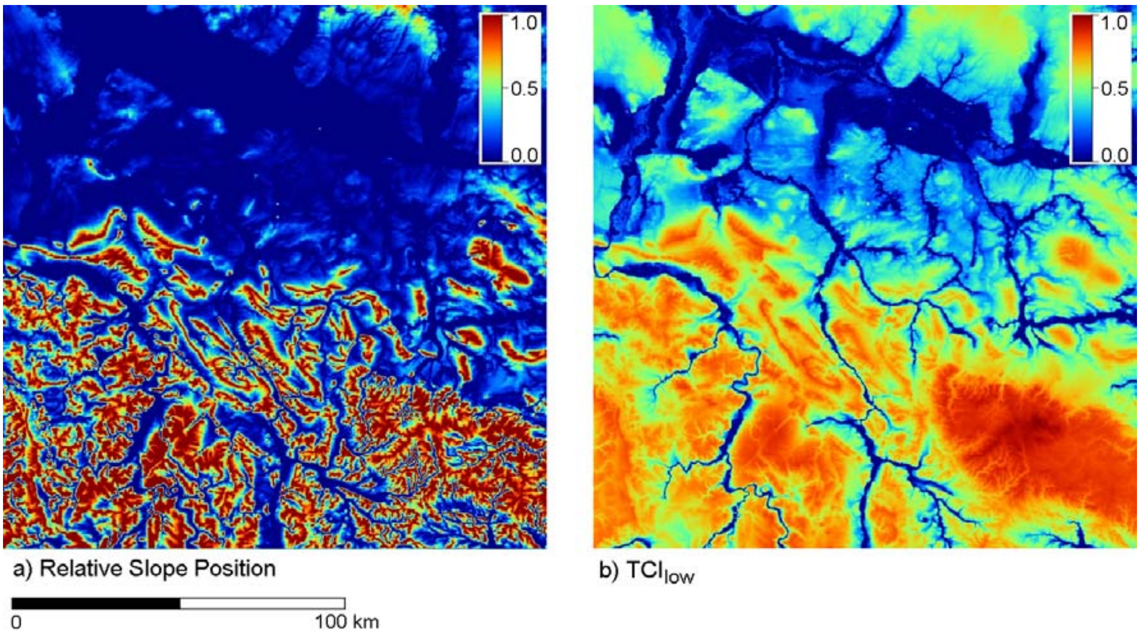


**Fig. XV.5. Examples for combined complex terrain parameters**

## XV.4 Delineating process areas and terrain classification

Another approach to support digital soil mapping is the delineation of process areas (terrain classification) which aims at three purposes:

a) **to provide zones for zonal kriging** (Wingle & Poeter 1996)
b) **to provide process areas** (areas of validity of different process parameters)
**c) provide terrain units with homogeneous conditions of soil genesis**

As some of the developments presented in this article are quite new, until now only a few attempts have been able to be made to apply delineated process areas for soil regionalisation. Mostly terrain classifications (c) have been used to support digital soil mapping.

### *XV.4.1 Digital geomorphographic maps*

Based on 20 years of experience in terrain (relief) classification (derived from DEM) several approaches have been developed to create "digital geomorphographic maps" to support digital soil mapping. Already very early during this development one fact became definite: *Classification and combination of some (simple) terrain parameters, fixed in any way, will not succeed*. Classifications which use fixed thresholds, e.g. for elevation or slope angle, will certainly cut homogeneous terrain features, produce "salt and pepper" effects and ignore local terrain features. Furthermore, combining the classes of the terrain parameters produces too many terrain units. For these reasons we disagree with the approach of terrain classification of **SOTER** (World SOil and TERrain Digital Database; ISSS, 1986).

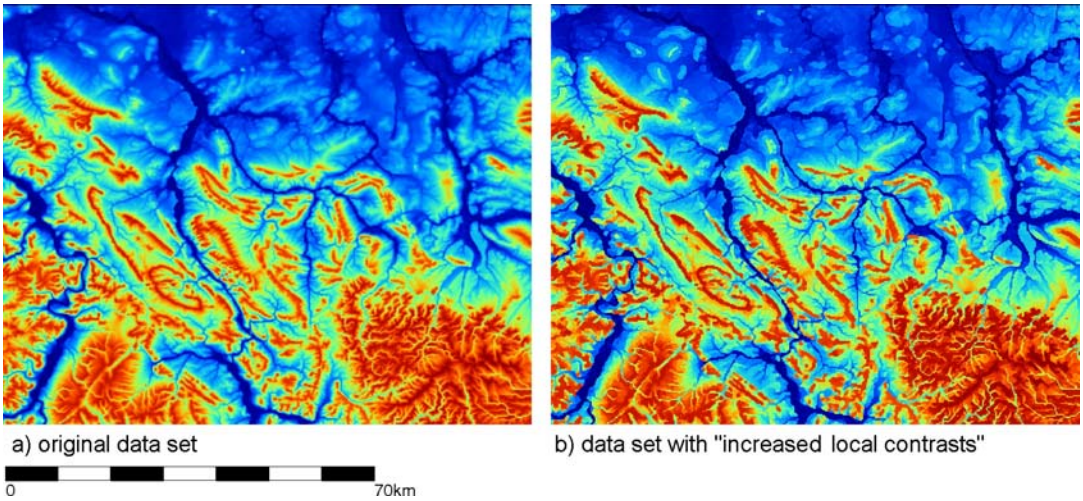


**Fig. XV.6. Increased local contrasts for TCIlow.**

Satisfactory terrain classifications should consist of a limited number of terrain units, should consider local terrain features and should be applicable for different landscapes. To achieve this aim, flexible procedures are needed which are able to automatically fit thresholds for classifications in a local spatial context. Based on various local and complex morphometric parameters, the developed methods first combined terrain profile analysis and cluster analysis and later on in addition segmentation techniques (known from remote sensing). At present, in particular pre-processed (see below) complex and combined terrain parameters are a basis for terrain classification.

**Segmentation techniques** and self-adjusting mechanisms to find local thresholds are used to delineate the desired terrain units. As there are always improvements possible, the methods are still under development. Although e.g. segmentation techniques generate inductive classifications, the system of terrain classification (terrain units) follows deductive methods at last. The classification system depends on the scale (mostly given by the spatial resolution of the used DEM), the landscape type and the demands of the customers. For a central European landscape a large or medium scale classification scheme to support digital soil mapping typically consists of:

- **bottom areas** (also including montaineous regions) – flattenings in bottom positions:
  - (holocene) flood plains and valley grounds
  - (pleistocene) fluvioglacial terraces
  - closed depressions (e.g. covered with lakes or bogs)
- **lower flat regions**:
  - (pleistocene) flat ground moraines
  - (pleistocene) end moraines, dunes
- **slopes** (montaineous regions) – areas of accumulation and erosion, solifluction, different rock outcrops:
  - downslope classification: relative slope positions, steepenings and flattenings, inclination
  - slope parallel classification: areas with convergent and divergent surface runoff
- **summit areas** (mountainous regions) – flattenings in top positions:
  - summit areas, subdivided by inclination and/or relative height

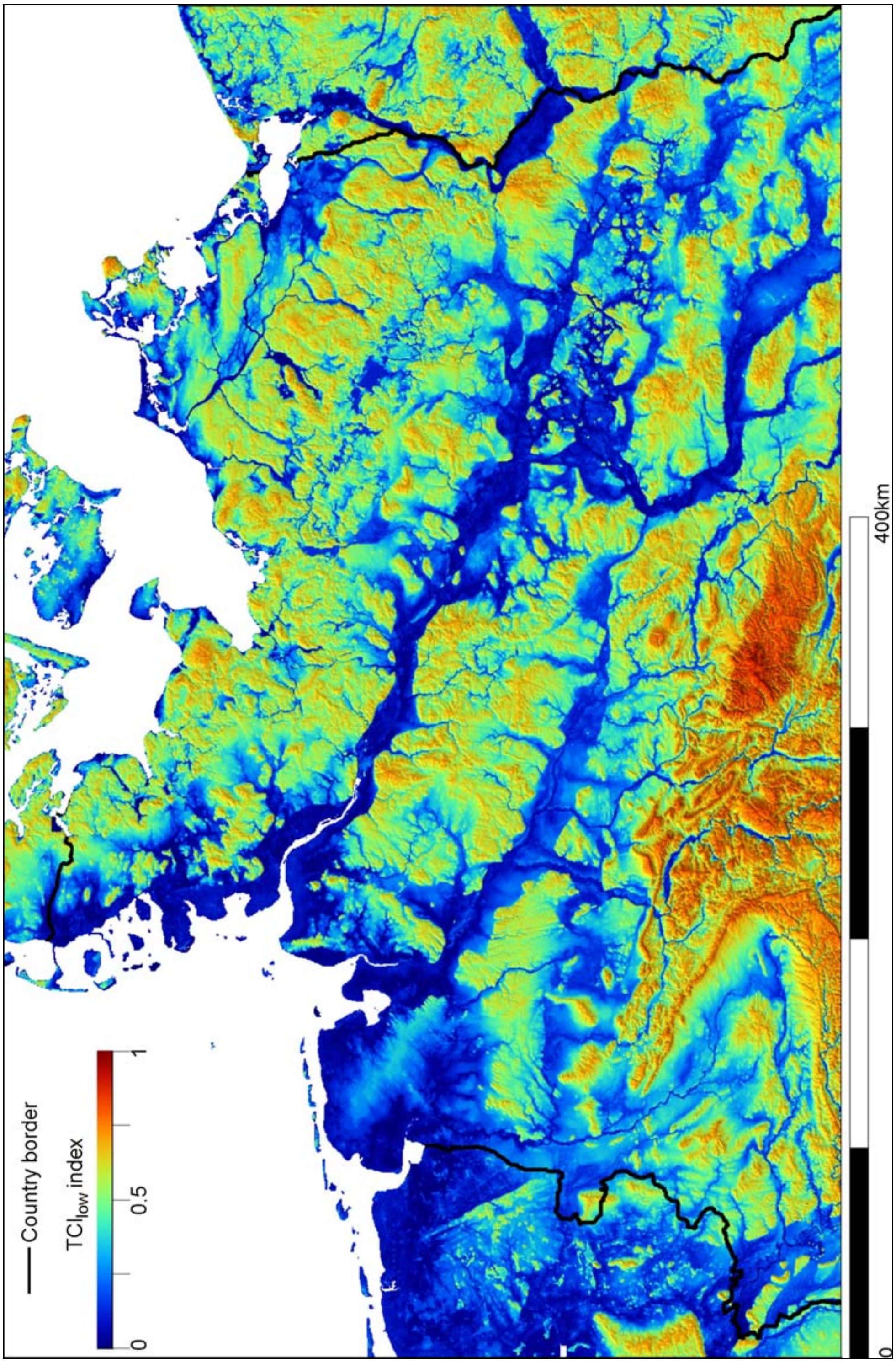


**Fig. XV.7. Combined morphometric terrain parameter Terrain Classification Index for lowlands. Shown for northern Germany and neighbouring countries (Netherlands, Denmark, Poland). The forest surfaces in SRTM3 DEM have only been eliminated in Germany because no CORINE data was available for adjacent countries.**

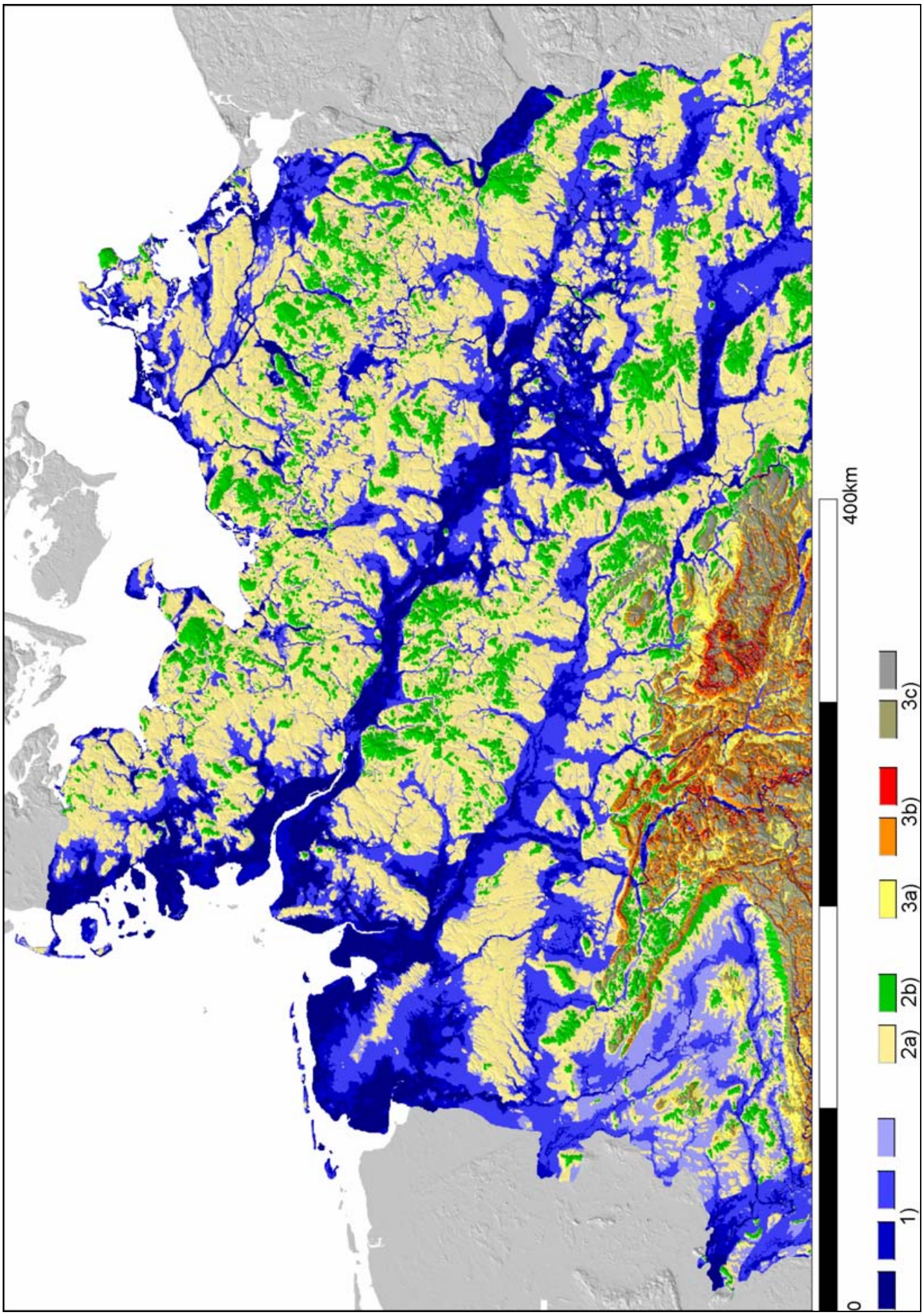


**Fig. XV.8. Main process areas in northern Germany. Aggregation of terrain units from the Digital Geomorphographic Map of Germany (GMK1000).**

**Legend:**

**1) marsh, holocene floodplains, pleistocene fluvioglacial terraces**
**2a) ground and end moraines (partly loess cover), sandy planes**
**2b) end moraines**
**3a) loess cover, terraces**
**3b) slopes**
**3c) summit areas**

The total number of terrain units normally varies between 12 and 15. It is obvious that this flexible classification scheme already contains geo-genetic components. The assignment of geo-genetic matters to morphometric terrain units derived from DEM has been done manually (deductive) up to now on the base of given maps of parent material (see further). There are no fixed thresholds for the classification system. To give just one example on how a self-adjusting mechanism to find local threshold works, a brief description of delineating valley grounds and river terraces follows. The values of the combined terrain parameter "terrain classification index for lowlands" ($TCI_{low}$) represent morphographic features in a local spatial context. They can be interpreted even geo-genetically. Going upwards from calculated channel lines a sudden increase of the values of the terrain parameter will indicate the border of the (holocene) floodplain or (more upwards) a slope to an upper river terrace. These increases (breaks) will be the later borders of the terrain units. To intensify the breaks or even to enforce hidden breaks an operation called *increase local contrasts in grid* (see Fig. XV.6) is used as a pre-processing step. Starting from the grid cells of the channel lines the adjacent grid cells are now analysed (following flow paths down to the channel lines). Within a given percentile range, referring to the $TCI_{low}$ values of the local channel line, the breaks are sought to identify the floodplains and terraces.

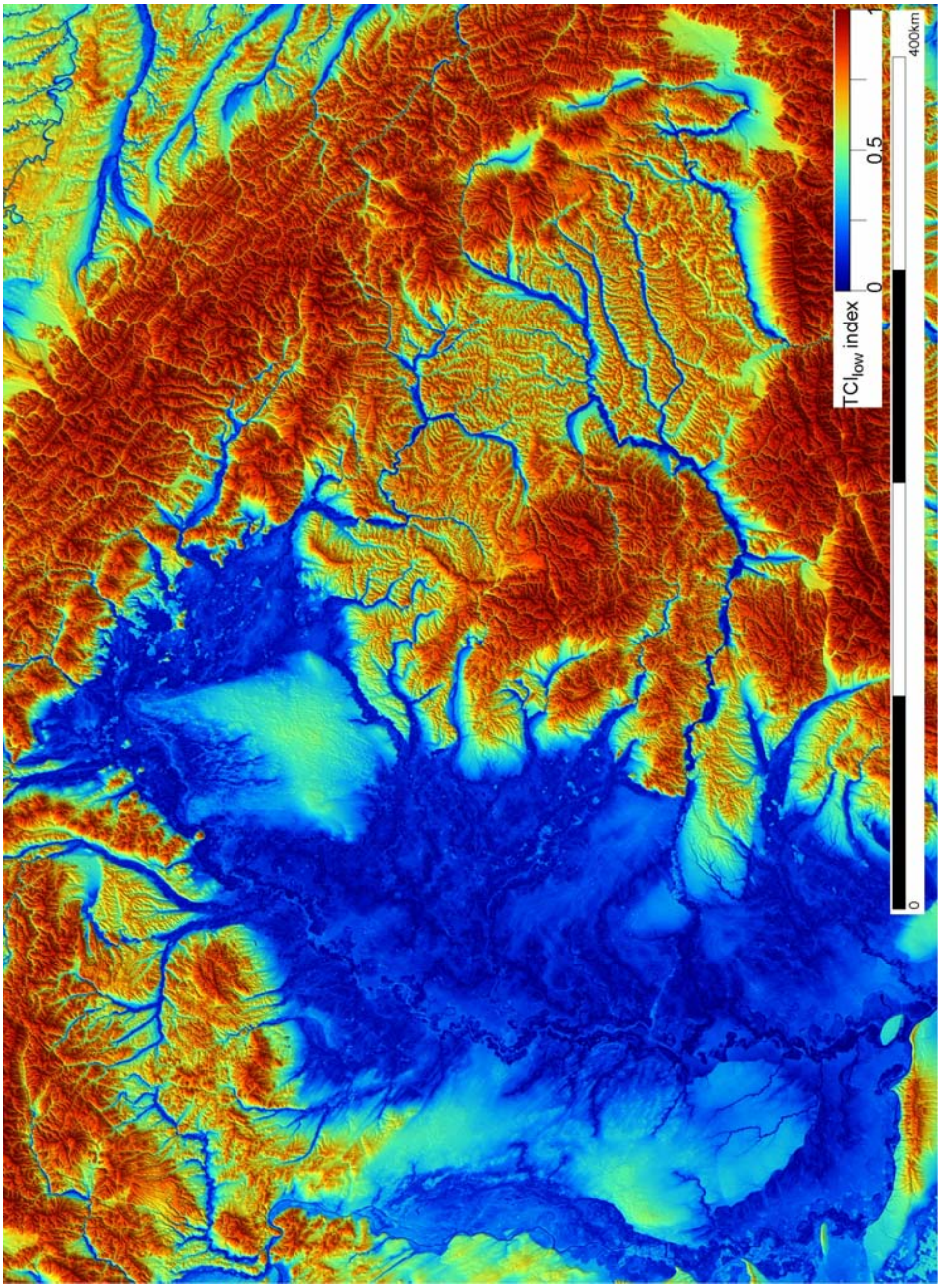


**Fig. XV.9. Combined morphometric terrain parameter Terrain Classification Index for lowlands (TCIlow) for the Hungary Great Plain and part of the Carpathians.**

Large scale digital geomorphographic maps (representing various stages of the development) have been produced to support digital soil mapping in several federal states in Germany: Lower Saxony (50 m grid cell size), Thuringia (25 m), Saxony (20 m) and Brandenburg (25 m, still under construction). A small scale digital geomorphographic map (250 m grid cell size, see Fig. XV.8), covering the area of Germany, is used by the Federal Institute for Geosciences and Natural Resources (BGR) for the homogenisation of soil maps from the soil surveys of the federal states of Germany at the scale of 1:200,000 – the European Union faces a similar problem.

Fig. XV.7 shows the combined terrain parameter TCIlow (Fig. XV.5b) for northern Germany and adjacent countries. The calculation is based on pre-processed SRTM3 DEM and DEM from local land surveys in Germany with a grid cell size of 250 m. This data set is one of main bases of the Digital Geomorphographic Map of Germany presented in Fig. XV.8. The original 17 terrain units from the shown part of the Geomorphographic Map have been generalised for downscaling in Fig. XV.8 by aggregating the terrain units by their content to the number of 11 (e.g. by summarising different slope units to one unit). Fig. XV.8 shows three main process areas: The differentiation between the main process areas (2) and (3) was manually done by the help of geological maps. The differentiation between process areas (2) and (3) on the one hand and process area (1) on the other hand was automatically realised by the described procedures. The local interpretation of the terrain units depends on geo genesis.

As Fig. XV.7 already shows, it will not be a problem to expand terrain analysis to other regions in the European Union. What is still missing is the standardisation of the terrain classification scheme. To underline the possibility to transfer the concept to other regions, Fig. XV.8 presents the combined terrain parameter TCIlow based on SRTM DEM (250 m grid cell size) for the Hungary Great Plain and part of the Carpathians as a pre-stage for terrain classification. This region was also processed by Dobos et al. (2005) to realise SOTER terrain units on the base of SRTM. The difference to the SOTER approach has already been discussed at the beginning of this chapter. Note that again some forest surfaces are recognisable in Fig. XV.9 because of the lack of CORINE data (Fig. XV.7) but a lot of terrain details are exposed in the Great Plain.

The presented approaches of terrain analysis and terrain classification may seem quite complex. Indeed the development has been time-consuming and has still not been finished yet. But as the methods have been realised as SAGA modules they are manageable (with adequate knowledge) and it will take only a few hours to create a data set as presented in Fig. XV.9.

### *XV.4.2 Parent material*

As mentioned above, information about parent material, taken from existing medium or small scale geological maps, is used to assign geo-genetic information to morphographic terrain units (as described for Fig. XV.8). In future, automatic procedures should improve this assignment. The outlines of the terrain units, which are automatically derived from DEM, will not be affected by this assignment. The result will be real *geomorphological* terrain units. As soil genesis is not only controlled by climatic conditions and relief controlled processes, parent material is also very important. To consider parent material within soil regionalisation, aggregated information from geological maps are used to delineate zones for zonal kriging. But until now no automatic procedures have been developed to implement this.

## XV.5 Geostatistical and Regression approaches

For the spatial estimation of soil properties from soil profile data we advice to use a multivariate regression approach in combination with kriging interpolation. With multivariate regression we determinate the soil genesis relevant terrain, climate and process parameters. The relevant parameters (examples from the testing site “Ebergötzen” Fig. XV.10a) are combined with a linear model to calculate the residuals of the soil profile data. For this 'detrended' dataset we have generated the semivariogram and have estimated the residuals with an ordinary kriging-interpolator to get a grided data set. The kriging-interpolator also estimates the error-variance of the interpolation, which can be used to mask areas with higher error-variance or to just declare the quality of the calculation in different areas.

The regression based approach handles the problem of the intrinsic random function and the important preconditions defined in Matheron (1963, 1973) to utilize kriging only in cases when the data set and the covered spatio-variations are not masked or superposed by a spatial trend or an external drift. The regression approach seperates the deterministic variations from the more stochastic variability, which is subsequently handled by kriging interpolation. Given the precise definition of process parameters and its causal relation to soil forming processes we assume a regression based approach to have more advantages than other pure geostatistical derivatives such as Ordinary Kriging, Co-Kriging and similar. Our approach entails a fair amount of analytical capacities and thus gains insight in factors affecting the variability of the target soil parameter (Fig. XV.10b).

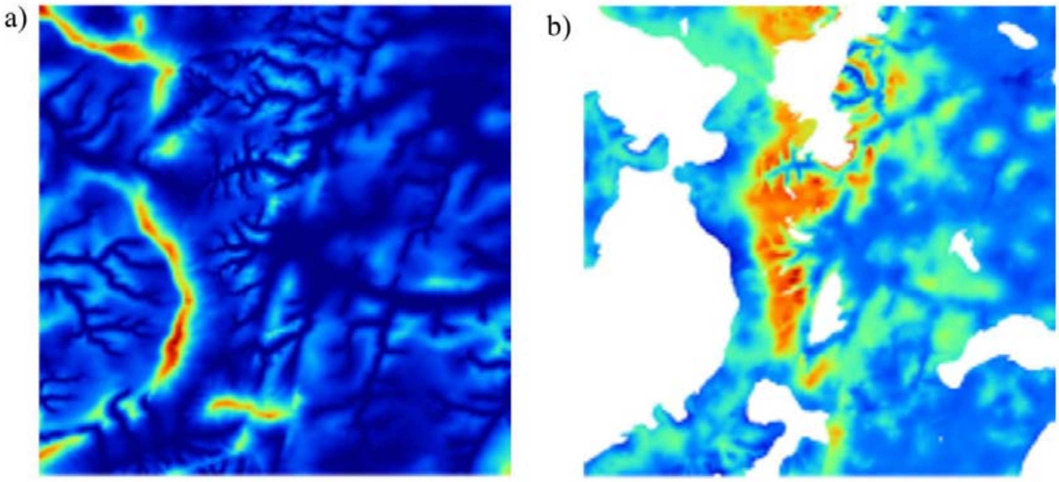


**Fig. XV.10. Multiple Regression approach: (a) process parameter 'altitude above channel line' as an example for an input variable of the multiple regression; (b) results: sand content in top soil layer (orange = high value, blue = low value), the white areas are masked due to the high error variance.**

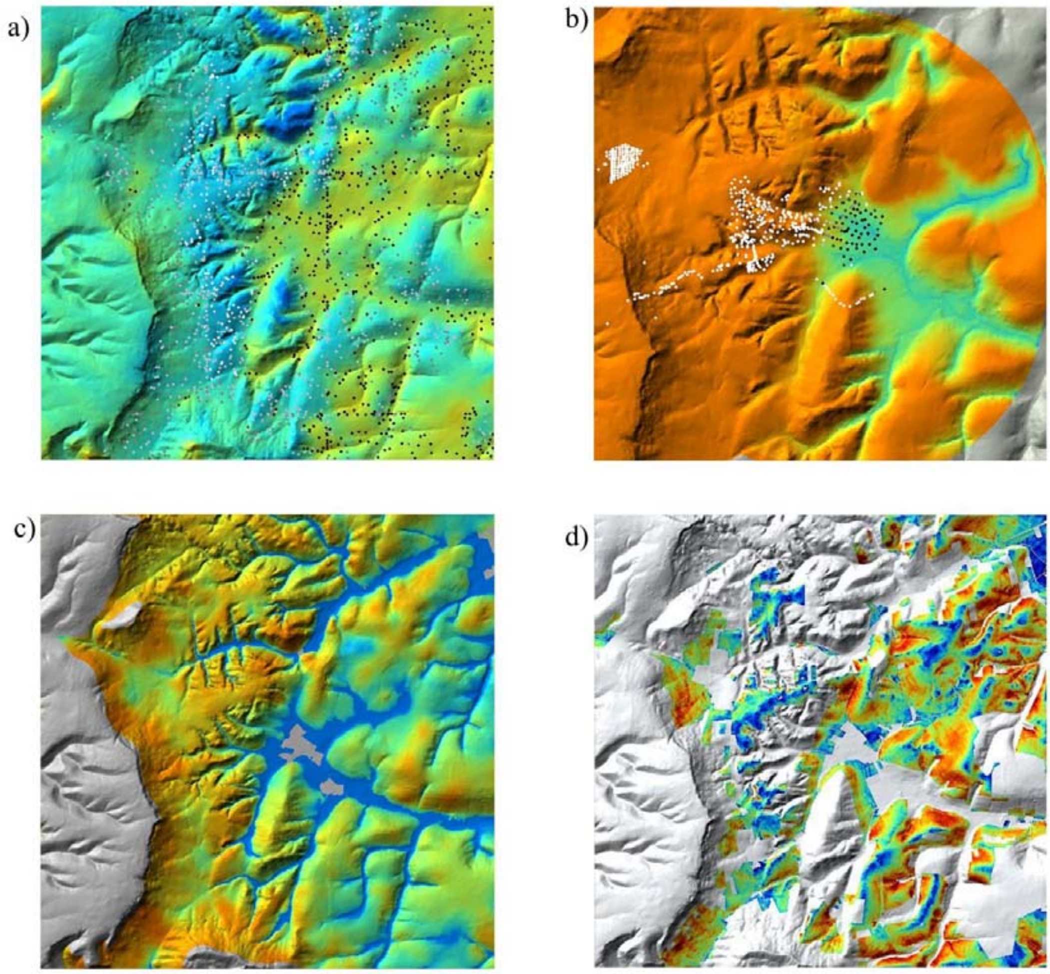


**Fig. XV.11. Results of the Regionalisation with Zonal Kriging: (a) silt content in top soil layer (orange = high silt percentage, blue = low percentage based on soil profiles of German Soil Assessment (black dots = high silt percentage, white dots = low silt percentage); (b) ground water below surface based on project profiles (black dots = low value, white dots = higher value than 2m/not measured); (c) derived parameter 'plant available soil water' (orange = low value, blue = high value); (d) derived parameter 'erosion risk' after modified USLE, scenario: all arable land is covered with maize (orange = high value, blue = low value).**

## XV.6 Using Pedotransfer functions with additional data

The results of the regionalisation process are functional soil databases coming as metric continuous grid data sets of basic soil parameters as texture (percentage of sand, silt (Fig. XV.11a) and clay content), bulk density, organic matter, ground water maximum below surface (Fig. XV.11b) and so on. Of course which basic soil parameter you can put into the regionalisation process depends highly on the content and the quality of the profile data. The output data sets are the base for many further applications.

In the case study “Ebergötzen” situated in the mountainous Lower Saxony in Northern Germany especially various geological parent material is responsible for the development of soil features. Therefore *Zonal Kriging* with different variogram functions in the particular zones was carried out. The process of generating the basic soil parameters here relied on soil profiles won by the German Soil Assessment, the process parameter 'altitude above channel line' derived from a DEM of 12,5 meter resolution and a digitised geological map (scale 1:25,000). The extent of the study area is about 100 $km^2$.

Based on these regionalisation results of multiple soil characteristics it is possible to calculate complex soil characteristics such as **available field capacity**. However, only the combination of several complex soil parameters can really provide us with data sets usable for practical application like **plant available soil water** as shown in Fig. XV.11c. It was calculated on the base of the regionalisation of available field capacity, depth of effective rooting level and capillary ascent from ground water. Including climate data and land use information as well as special terrain parameters (e.g. modified LS-factor for USLE) it is also possible to calculate parameters for resource protection such as soil erosion risk (Fig. XV.11d). In times when farmers are faced with requirements due to cross compliance these data sets should be an improvement for risk assessment.

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# XVI. Towards Soil Information for Local Scale Soil Protection in Slovenia

Borut Vrščaj

Agricultural Institute of Slovenia, Centre for Soil and Environmental Research
Hacquetova 17, SI 1000 Ljubljana, Slovenia
Tel.: + 386 1 2805 290; Fax: + 386 1 2805
Borut.Vrscaj@kis.si

**Summary**

*Two important documents announced the upcoming changes in the national soil protection legislation: the Thematic Strategy for Soil Protection (European Commission, 2002) and the Proposal for a Directive for the Protection of Soil (European Commission, 2006b). The paper briefly presents the general structure of European small scale digital vector soil information, the work of two soil expert groups established by the European Soil Bureau Network, and digital soil mapping research activities in the world. Soil and environmental protection activities are implemented at the local scale, for which reliable and accurate soil and related environmental information is required. In Slovenia relatively abundant state-wide soil information is available and has been intensively used. The structure of the digital soil map at a scale of 1:25 000 is briefly explained and the use of digital soil information in the past is presented. Slovene soil research institutions and the available general purpose soil data are introduced. The paper describes current and planned AIS activities for the improvement of the Slovene soil data sets to meet the quantitative and quantitative requirements for: i) supporting local scale soil protection activities, ii) the adaptation of existing agricultural practices towards more sustainable use of soil; and iii) groundwater protection. The conceptual model for the improvement of the existing soil information and the elaboration of the large scale soil datasets for local scale soil protection is presented. The required scale/resolution and the major activities for soil data improvements are discussed. The paper briefly presents the auxiliary large scale datasets needed for digital soil mapping (DSM) methods. The empirical knowledge based DSM method developed in the Javorniki test area is briefly described.*

## XVI.1 Introduction

The soils of Europe are subject to degradation, threatened by several processes including soil erosion, decline in organic matter, pollution, sealing, and compaction. In 2002 the European Commission published *Towards a Thematic Strategy for Soil Protection* (European Commission, 2002), a document which was followed by additional two documents released in the fall of 2006: (i) the *Thematic Strategy for Soil Protection. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions* (European Commission, 2006b), and (ii) the *Proposal for a Directive of the European Parliament and the Council for Establishing a Framework for the Protection of Soil and Amending Directive 2004/35/EC* (European Commission, 2006a). All three documents reflect the awareness of the environmental role of soil and its importance for sustainable development. The documents can be considered to be an answer to the concerns regarding soil degradation and an important step towards soil protection and the preservation of its functions. They represent a basis for binding soil protection legislation and, consequently, the related soil protection activities within the EC countries. All three documents, and especially the *Proposal for a Directive*, will, when accepted, represent the platform for the development of national soil protection legislations in the EC.

The activities needed to implement and conduct the soil protection policy require reliable and accurate soil and related environmental information. The available soil databases in Europe are relatively rich. These countries have been collecting soil information for decades. A significant quantity of collected information is now available in the form of digital maps and georeferenced analytical data (Jones et al., 2005). Soil maps have been published and/or integrated into national and continental soil information systems. The information collected by countries and regions is similar, yet it varies significantly as regards scale, content, size, accuracy, and analytical procedures. A comparison of available data sources shows that few European countries have soil information available in a form, scale, and accuracy suitable for local scale soil quality management and the implementation of the upcoming soil protection legislation.

The **Agricultural Institute of Slovenia** [www.kis.si] is a governmental research institution founded in 1898 (AIS). It supports the activities and programmes of the Ministry for Agriculture, Food, and Forestry (MAFF), the Ministry of the Environment and Spatial Planning (MESP), the Chamber of Agriculture and Forestry, the Agricultural Extension Service, and other governmental bodies, and it supports the farmers and the local communities. Within the AIS, as a part of the Central Laboratories, the Centre for Soil and Environmental Research was formed (AIS).

This article very briefly describes digital soil information, the digital soil mapping, and soil information activities, and common digital soil data structures in Europe. In the second part it briefly presents the soil research institutions in Slovenia and available soil databases. The third part describes current and planned AIS activities for the improvement of the Slovenian soil data sets in order to meet the quantitative and quantitative requirements for: i) supporting local scale soil protection activities, ii) the adaptation of existing agricultural practices towards more sustainable use of soil; and iii) groundwater protection.

## XVI.2 Data for soil, land, and environmental protection

### *XVI.2.1 Towards soil protection at the European level*

The required soil protection activities in Europe are determined in the above mentioned documents. The EC Joint Research Centre (JRC Ispra) and the European Soil Bureau Network have established two expert working groups to identify the information, data sources, and techniques needed to improve the soil information for soil protection activities at the pan-European level. Soil inventory experts within the European Soil Bureau Network joined the **Soil Information Working Group** (SIWG) to provide scientific and technical support for the identification of areas at risk from soil threats as defined by the European Commission (European Commission, 2002): Soil Organic Matter Decline, Soil Erosion, Soil Compaction, Salinization, and Landslides. In the SIWG report (Eckelmann et al., 2006) an overview of the common criteria and approaches for identifying risk areas due to soil threats is presented. The report also introduces the data sources, accuracy and resolution for national (TIER1) and regional (TIER2) levels.

Soil digital mapping experts formed the **Digital Soil Mapping Working Group** (DSMWG) to serve as an advisory board to the European Soil Bureau Network for identifying potential digital soil data sources, to advise on database harmonisation, and to define the needs for digital soil functional mapping. The DSMWG produced a report (Dobos et al., 2006) which presents the relevant sources of available pan-European digital soil mapping (DSM) and required auxiliary information and different types of DSM models, describes the accuracy assessments, presents the visualization possibilities, and introduces a few selected case studies on the mapping of soil functions and threats.

### *XVI.2.2 Soil data and its general structure*

Generally, the georeferenced soil datasets in European countries are vector based. The soil maps are polygon layers where the basic spatial objects are soil mapping units (SMU) polygons. They are characterized, depending on the individual soil map, by one or more soil typological unit (STU) soil types. This structure is very commonly used in medium to small to scale soil databases. The 1:1M Geographical Soil Database of Europe has the same structure (Bouma et al., 1998; European Soil Bureau Scientific Committee, 2001). SMU units can contain an unlimited number of STUs. The spatial location and the extent of individual STUs within the SMU are not determined; only a proportion of individual STUs within SMU is given as a percentage. Recently vector-based soil maps have been converted to raster layers representing SMUs or derived information on the individual soil properties in order to facilitate easier and faster processing and cell-by-cell modelling. The measured soil data are available as georeferenced points. The observed and analysed properties of individual soil horizons and profile locations are described by the information stored in attribute tables of various structures linked to the points with appropriate GIS software (Hollis et al., 2006). Polygonal and point soil datasets represent a source of information for different modellings (Dobos et al., 2005)

### *XVI.2.3 Other relevant information for soil-landscape processing*

Auxiliary soil and landscape related georeferenced information is needed for soil-landscape modelling. Being a relief one of the primary pedogenetic and soil property determining factors, digital elevation models (DEM) and DEM-derived information represent one of the main input modelling information sources. From a DEM, a number topography describing parameters can be derived: from almost trivial information such as slope, exposition, altitude, and shading, to the more complex such as potential drainage density, curvatures, generic landforms (MacMillan, 2001) etc. On a European continental scale 90 m (or conditionally 30 m) SRTM elevation models are available [http://srtm.usgs.gov] and after appropriate corrections and modifications they can be used for soil–landscape modelling.

#### *XVI.2.4 Spatial requirements*

Europe is characterised by a variety of very diverse landscapes (Meeus, 1995) which by themselves represent an obstacle to obtaining a satisfying set of suitable soil and soil related parameters or a uniform dataset of required accuracy. In regions with heterogeneous soil cover the resolution of the 1:1M GSDBM database cannot be considered to be sufficient for modelling soil threats (Eckelmann et al., 2006). The existing pan-European Soil Geographical Database needs to be spatially improved (Daroussin et al., 2006). The implementation of the soil protection strategies and activities determined by the upcoming legislation is carried out on a regional and, above all, local/municipality level. The existing country information needs to be updated and supplemented in order for it to be suitable for local use. The existing soil information has to be improved in terms of better semantic information and improving the geometry of soil maps.

## XVI.3 The use of the Digital Soil Mapping Techniques

Digital soil mapping (DSM) is the computer assisted elaboration of digital soil maps and georeferenced information on soil properties. DSM uses geostatistical and mathematical methods that combine measured and observed soil information (soil profile data and vector based soil maps) with other correlated environmental information. DSM methods and techniques have been intensively researched and developed in the last decade (McBratney et al., 2003). The correlated auxiliary information used in DSM processing are related to the main pedogenetic factors as they were identified by Dokuchaev in 1898 in his equation $soil = f(cl,o,p)t_r$[13] and later extended by Jenny (1980) to the ecosystem equation: $l,v,a,s = f(cl,o,r,p,t,\ldots)$[14]. Among pedogenetic factors the terrain and landform information represents essential information for soil-landscape modelling. Intensive research has been carried out to determine and derive land form information using DSM techniques (Burrough et al., 2000; MacMillan, 2001; Hengl and Rossiter, 2003; MacMillan et al., 2003) and to define the appropriate DEM resolution (LandMapper Environmental Solutions, 2003). The landform information is combined with geostatistical (Goovaerts, 1999) or combined methods (Burrough et al., 1997) to perform quantitative soil mapping (Hinojosa et al., 2004) or to derive thematic data on individual soil properties (de Bruin and Stein, 1998; Heuvelink and Pebesma, 1999). The applications of fuzzy logic in soil science are wide-ranging and yield good results in numerical classification soil mapping (Zhu et al., 1996; De Gruijter et al., 1997; Mays et al., 1997; McBratney and Odeh, 1997; McBratney et al., 2002).

The empirical knowledge on soil-landscape relationship is combined with other environmental data and integrated within the DSM (Zhu and Band, 1994; Zhu, 1999; Bui, 2004; Langanke et al., 2005). Several authors have explored the possibilities of deriving or estimating thematic soil information from imprecise soil data (Lagacherie et al., 2000; Cazemier et al., 2001). The functional soil horizons are used as keys for developing rule-based continuous soil modelling system (Lamp and Ameskamp, 1998). Sediment yields were modelled in Italian catchments (Rompaey et al., 2005). The model for carbon sequestration was created by Wang and Medly (2004). The DSM and related methods and techniques are explored also by other numerous researchers not mentioned above.

## XVI.4 Available soil information in Slovenia

#### *XVI.4.1 Soil research institutions in Slovenia and the availability of the soil information*

The history of the soil research in Slovenia started in the 1930's when soil data was collected for mainly plant nutrition purposes. The collection of general multipurpose soil information was carried out within a context of individual land aggregation and land amelioration projects after the Second World War. The research and educational institutions in Slovenia where soil is investigated to various degrees are:

- **The Center for Soil and Environmental Science of the University of Ljubljana –** CSES [www.bf.uni-lj.si/cpvo] has generalised the semantic part of the DSM25 and have published the Soil Map 1:250,000 (Lobnik et al., 2006). CSES carries out the general soil data research within different projects while the plant nutrition and the soil pollution data collection are carried out to a minor extent.
- **The Agricultural Institute of Slovenia**, Central Laboratory, Centre for Soil and Environmental Research (AIS). AIS carries out soil fertility and plant nutrition research and provides services, builds and maintains soil databases, improves the existing digital soil maps and georeferenced data, and carries out research projects related to the sustainable use of agricultural soil. The AIS soil analytical laboratory participates in ring tests and is accredited by the Slovene and the French Accreditation Agency. In 2005 the 7487 soil samples for a plant nutrition

[13] Where cl is regional climate, o is vegetation and animals, p is the geologic substrate and $t_r$ is relative age of soil.

[14] *l*, *v*, *a*, and *s* are system properties: *l* is total system (e.g. system respiration, total C content), *v* is vegetation (e.g. biomass, communities), *a* is animals, *s* is soil (e.g. pH. Texture, humus content…). State properties are *cl*, *o*, *r*, *p*, *t* where *cl* is the environment climate, *o* is the flora and fauna as a pool of species and genes, *r* is topography and water table, *t* is time.

control were collected and analysed. A significant portion of these samples is currently being georeferenced and stored in a soil information system developed by the AIS. Within recent soil research projects, 100 sets of topsoil data is being collected in Ljubljana municipality and at 100 locations across Slovenia which are representative as regards describing the most frequent soil types.

- **The Slovenian Forestry Institute** – SFI [www.gozdis.si] carries out research on forest soils. It collects forest soil data information and has information on 100 forest soil profiles in digital form and an additional 200 are to be added within the framework of a BioSoil research project (Simončič, 2006).
- **The Agricultural Extension Service of the Chamber of Agriculture and Forestry of Slovenia** collects and analyses soils for plant nutrition purposes. Six regional laboratories process a large number of soil samples. The information is not georeferenced.
- **The Faculty of Agriculture of the University of Maribor**, Chair of Chemistry, Agrochemistry and Soil Science [http://fk.uni-mb.si] teaches soil science. Soil research is carried out to a limited extent within the framework of research projects.
- **The Geographical Institute of the Pedagogical Faculty of the University of Maribor** carries out soil research for educational purposes. The data on collected 150 soil profiles are not georeferenced (Vovk Korže, 2006).
- **The Department of Geography of the Faculty of arts of the University of Ljubljana** [http://www.ff.uni-lj.si/oddelki/geo/eng/index.html] and the Karst Research Institute [http://kras.zrc-sazu.si/] sample and describe soil within teaching programs and several research projects. The researchers report the collection of 200 sets of soil profile data, which are georeferenced but not yet in a digital form (Repe, 2006).
- **The Erico environmental institute** [www.erico.si] carries out environmental research projects, some of which are also related to soil pollution.

### *XVI.4.2 General purpose soil information*

The collection of general purpose soil data and the elaboration of a semi-detailed soil map were initiated in the early sixties when systematic field mapping and soil profile data collection started. The work was conducted and carried out within the CSES. The main goal was to elaborate a soil map on a scale of 1:25,000. The activities were financed by Slovene research funds and later in the eighties mainly by the MAFF. The project lasted, with several interruptions, until 1997, when an operative soil map 1:25,000 was completed for the whole Slovene territory.

### *XVI.4.3 Digital Soil Map 1:25,000 (DSM25)*

The use of digital soil information began in 1987. After initial research, the testing of different software and the establishment of the digitising procedures in the programme of elaborating of the **DSM25** were prepared. The digitalization officially started at 1992 and was entirely financed by the MAFF. The Yugoslav soil classification was used which was adapted to better fit the distribution and specifics of Slovene soils. The need for a comprehensive Slovenian classification system has been recognized during the DSM25 digitalization. To accommodate this, a provisional Slovene soil classification system was elaborated, which is still in use. The DSM25 was completed for the whole territory of Slovenia, and following a revision by FAO experts, it was delivered to MAFF in 2001 together with 1680 soil profiles (SP). The DSM25 is a polygon-based vector soil map. The basic spatial objects are SMU polygons composed of up to three main STUs. The spatial location and the extent of individual STUs within the SMU is not determined; only the proportion of individual STUs is given as a percent (Vrščaj and Lobnik, 1999).

### *XVI.4.4 Soil profile data (SP)*

The Soil Profile data is a georeferenced point data set in which three different sets of semantic information are linked to the spatial object – points:

- The **profile location data**: the name of the place, slope, land use, altitude, vegetation, parent material, etc.
- A **description of the main soil horizon morphological properties** such as structure, texture (finger test), roots, moisture, stoniness, color, redoximorphic features, etc.
- The **analytical information** comprising the pH, organic matter content, sand, fine and coarse silt, clay, total N, AL extractable P and K, and base cation. From the measured data the organic C, CEC, Ca, Mg, K, Na, base saturation and texture class are computed. Pedotransfer functions are used at AIS to assess more complex properties on an individual soil horizon basis and summary soil profile data.

### *XVI.4.5 The use of the national-wide digital soil data in Slovenia*

The development of the IT technology facilitated intensive use of digital soil data (Vrščaj et al., 2005) within different research projects, among which the most representative are probably the following:

- **Land suitability** for agriculture: The GIS raster model for the definition of the land suitability for different agricultural uses was elaborated. The basic information used in the models were (i) the soil suitability for agricultural use (fields and grassland), (ii) soil parameters relevant to define soil quality for orchards and vineyards, iii) derivates of 100 m DEM, and iv) the parameters which defined agricultural techniques for each of the elaborated types of agricultural land use. The results of the project were six raster databases at a resolution of 100 m representing spatial information on soil suitability for a certain agricultural use: arable land, vineyards, orchards, hops, grassland, and olive growing.
- **Areas affected by a drought 2000**: A GIS raster model was designed to elaborate a 100 m raster database of areas affected by severe drought. Besides DSM25 polygons, the basic model input data were soil parameters (water retention capacity), expert classification of soil-systematic units, precipitation data, and 100 m DEM.
- **Natural limitations for agriculture**: A 100 m raster database showing areas with limited conditions for agricultural production was elaborated. The developed raster GIS model uses the DSM25 polygons, DSM25 attribute data, empirical classified soil-type suitability for agriculture, 100 m DEM derivates, and 30-year average precipitation (Prus et al., 2000).
- **Natura 2000 and habitat protection**: Within the FP5 SPIN project [www.spin-project.org] the DSM25 was used to predict the spatial locations and extent of the protected habitats in the Javorniki project test area in Slovenia (Langanke et al., 2005). The results were 25 m raster maps of the distribution of the selected protected habitats.
- **The National Irrigation Program**: Proposed irrigation areas in Slovenia were analysed and classified according to 6 soil properties. As a result, 65 maps were plotted where the soil suitability for irrigation was shown according to 5 categories (Prus and Vrščaj, 1994).
- **Highway construction**: Proposed routes for several highway sections were evaluated. The loss of the soil resource and the environmental impact on agricultural production, was estimated.
- **Land capability**: The methodology of using the DSM25 within a GIS model respecting the current Slovenian soil evaluation legislation (GURS, 1984) was developed.

### *XVI.4.6 The availability of soil information for local soil protection*

From the projects described above it can be concluded that the majority of such were carried out on a national or regional scale. None were carried out on local scale for soil protection activities within municipalities. Raster processing was used at the 100 or 25 m cell size resolution. When soil vector data were processed the DSM25 polygon geometry was used. The recent soil datasets can be considered to be national soil inventory datasets. At the moment, in spite of the available relatively abundant state-wide soil information, Slovenia does not have soil information of a quality and quantity suitable to satisfy the requirements for local scale soil-landscape processing. The local scale soil protection databases and information system(s) have yet to be established. As of 2006 the core digital datasets on Slovenia which can be used for the spatial and semantic improvement of soil information are the following:

- The Soil Profile Data
- The Digital Soil Map at a scale of 1:25,000
- The Soil Pollution Monitoring Data
- The georeferenced Soil Fertility Data

## XVI.5 Towards soil information for local scale soil protection in Slovenia

### *XVI.5.1 Soil protection and soil quality management activities*

At AIS the main activities required for soil protection and soil quality management at a local scale in Slovenia were identified. The most important actions were grouped as follows:

- **Ground water protection** measures: A program for the improvement of agricultural practices should be established for ground water threatened areas which are, primarily, areas of shallow sandy Dystric and Eutric Cambisols formed on gravel deposits which are important groundwater sources. The agricultural practices, crop selection and rotation, and tillage systems should be revised and adapted to the soil type / soil properties.
- Agricultural areas suitable for the application of **sludge and slurries** should be identified on the basis of soil properties and auxiliary environmental data. Soil heavy metal pollution from non-agricultural sources should be assessed for areas close to (former) industrial centres. Systematic **agricultural soil pollution monitoring** should be initiated. The information from both sources together with other soil property data should be collected within a soil pollution monitoring information system.
- **Improvement of agricultural practices**: The current techniques and technologies should be adapted towards greater sustainability of agricultural production. The main tasks are the sustenance of soil fertility, increasing soil

organic matter content, suitable use of fertilizers, and the prevention of soil compaction and the pollution of groundwater resources. The adaptation of tillage systems should follow actual on-site needs of individual farms regarding the spatial diversity of soil properties and the soil suitability. The activities should be carried out with the close collaboration of the Agricultural Extension Service.

- **Organic matter content**: According to some research, the OM content in Slovenian soil is, in comparison with other European countries, relatively high. In spite of that, it is recognised that the OM level should be increased to improve soil quality, protect ground water, introduce low-tillage practices, prevent droughts, and sequester $CO_2$ (Sušin and Vrščaj, 2006).
- The prevention and mitigation of **natural disasters**. The local scale general soil property data combined with the auxiliary environmental information is used in drought, floods, and landslide risk environmental analyses.
- **Forecasting the impacts of soil sealing on the soil resource**: New soil information on the capacity of soil to perform main environmental functions should be elaborated on the basis of improved datasets. The databases should be used to distinguish *good* soil from *bad* soil in spatial planning in order to assess the impact of urban sprawl on the performance of soil functions, and to introduce soil environmental quality in the spatial planning process.

### *XVI.5.2 The activities needed*

Soil protection activities and actions as regulated by the upcoming legislation are carried out at the local level – within a municipality or a watershed. With an awareness of the limitations of the existing Slovene state-wide datasets for use in local scale soil protection, the soil data improvements were foreseen at AIS. The most important activities that have to be carried out are:

- The establishment of a national set of soil quality indicators (SQI) (primary and secondary soil properties)
- Further collection of measured soil data in soil information system, and the elaboration of data interpretation and reporting routines within the SQL environment
- The development of a set of pedotransfer functions and inference models for air and water-related soil properties and their application to existing datasets
- The development of soil spatial and soilscape inference systems adapted to Slovene landscapes and data availability
- The improvement of the spatial resolution and accuracy of state-wide DSM25 using high resolution DEM and EO data and DSM techniques
- Elaboration of soil maps at local scale resolutions (e.g., 1:10,000) for the areas affected by environmental and soil threats using a combined approach of DSM methods and field work
- The elaboration of raster data on secondary soil properties at a resolution suitable for use at the municipality/watershed level using DSM methods

Additionally, the collected soil information has to be adequately interpreted and available also for non-expert use. Two main activities need to be established:

- The enhancement of multi-functionality and the applicability of data with an emphasis on the needs of the target end-users groups
- The improvement of the accessibility of soil information for non-soil expert use and educational purposes; raising awareness

### *XVI.5.3 Georeferenced soil–related and auxiliary environmental information*

Auxiliary soil and soil related environment information is required in soil-environmental modelling. The main databases and information needed for soil protection activities are already available in Slovenia. At the AIS the following datasets are in use:

- **Digital Ortho-Photo Imagery** (DOF): The black and white DOF imagery in 0.5 m resolution (DOF5) covering the complete state territory is available in different time intervals. In March 2007 a colour version 2006 will be available.
- **DEM**s: 100 m, 25 m, and 12.5 m cell resolution DEMs are available for the territory of Slovenia. 5 m DEM originating from the DOF5 processing will be available in March 2007. The 12.5 and 5 m resolution DEMs are required information for the mountainous/hilly Slovene topography.
- **Lithology/Geology**: By the end of 2008, the digitalization of lithological/geological maps on a scale of 1:25,000 will be finished for the entire territory. By that time a 1:100,000 georeferenced raster geological/lithological map will be available.
- The **Agricultural Land Use Map** is a polygon layer interpreted from the DOF5. Polygons hold the information of the agricultural land use categories. The first version of the database was generated in 2002, followed by the

2005 version while the 2006 version is expected to be released in early 2007. The layer is expected to be updated at 2-3 year time intervals.

- The **Areas of Uniform Agricultural Use** database shows the polygons of uniform agricultural use within individual farms. The attribute dataset consists of the ID of the individual area, a farm ID, and a land use code. The polygon borders generally follow the cadastral borders. The database is the basis for direct payments, subsidies, and other MAFF administrative affairs.
- The georeferenced **Meteorological Data** on precipitation and temperatures can be elaborated for any time period at the Slovenian Environmental Agency. The information is generally available at 1 km cell size raster format but can be conditionally delivered at 100 m resolution.
- The **Ground Water Protection Areas** polygon layers are available at the MESP.

To the available data listed above additional, at the moment not available, information has to be added, of which the earth observation data is the most important.

### *XVI.5.4 The required scale of soil data*

Slovenia measures 20,256 km$^2$. Within this relatively small area a great diversity can be found. Altitudes range from 2864 m to sea level. Different lithologic and geomorphologic features are present. Average yearly precipitation ranges from 1600 mm in the West to 700 mm in the East. All this combined with the diverse topography results in a variety in the distribution of soil types. The regional criteria, as set for Europe, are in the case of Slovenia comparable to the national level.

The diversity of topography and soils in Slovenia and the availability of relatively high resolution auxiliary information (including the Areas of Uniform Agricultural Use database on the farm level), enable/require an elaboration of soil information of comparable scale/resolution. According to evaluations at AIS, for the important agricultural and ground water protection areas, the general scale of vector based soil information maps is 1:10,000, while the cell-size of raster base maps of primary and secondary soil properties is set at 5 m.

### *XVI.5.5 The AIS/CSER approach*

The end-user oriented soil information model is composed of three steps. Firstly, the existing soil maps and soil related information are updated and improved using the additional collection of measured data and DSM methods. The second step represents the adaptation and elaboration of the pedotransfer functions to derive thematic maps of primary and secondary soil properties (soil quality indicators) of adequate resolution. The third step is the elaboration of indexing and scoring computer algorithms which convert the technical soil information to indexes of soil quality/suitability, in a form understandable to non-soil experts. Fig. XVI.1 presents the process of downscaling soil information and indicates the main required fields of research.

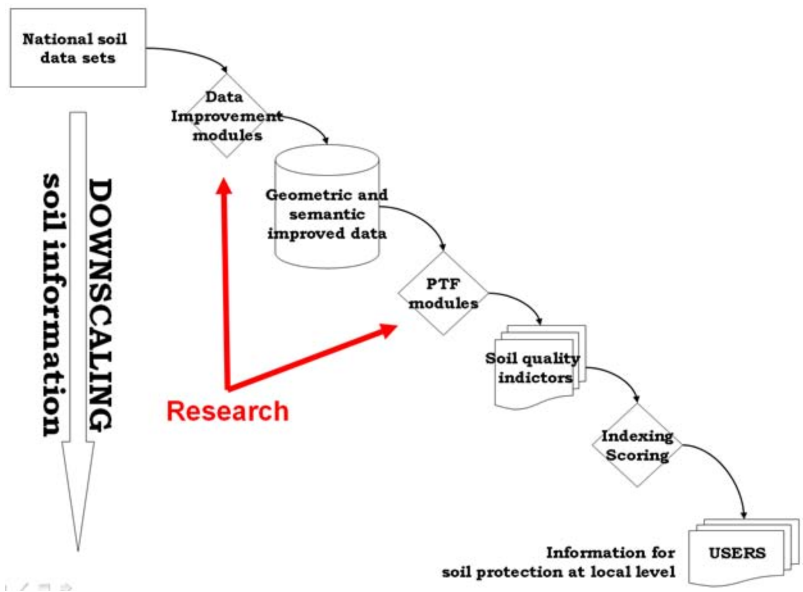


**Fig. XVI.1. The general procedure for downscaling the nation wide soil information for local level soil protection.**

### *XVI.5.6 Three steps of downscaling soil information*

**I. The DSM stage**: In the first stage the existing vector soil information is improved using suitable **DSM methods** adapted to the situation in Slovenia. Regarding the state of measured soil information (relatively low number of soil profiles, large areas of non-existent digital measured data), the low level of detail of the DSM25 in some areas, and the general high level of topography and soil diversity in the country, the combined DSM method using expert knowledge and data-mining approach is anticipated to yield appropriate results. The vector (polygon and point) and raster information is gathered in the soil information system. The process itself entails continuous activity and is carried out within different research projects and regular AIS activities.

**II. The PTF stage** encompass the rasterization of the polygon information to suitable resolution. The pedotransfer functions and soil spatial inference functions are used to derive primary and secondary soil properties from primary soil data (maps and measured point data) and auxiliary soil-related and environmental information. The results are individual raster thematic layers of secondary soil properties / soil quality indicators.

**III. The Indexing stage** encompasses computer algorithms based primarily on Boolean logic. The algorithms are implemented within a GIS environment and the information on individual layers of primary/secondary soil properties is processed on a pixel-per-pixel basis to elaborate *suitability* and *risk* maps. The indexing algorithms are divided into two groups following the **environmental protection** aspect and the **goods and services** approach.

The results of the first group are the raster datasets and maps indicating the soil-related environmental risks and the soil functional maps – the capacity of soil to perform environmental functions. The algorithms from the *goods and services* group assess the suitability of soil/land for a certain use or for the production of certain goods. The resulted maps should be interpreted and available as index-based information for the targeted end-user groups, mainly non-soil experts (Fig. XVI.2). The system can be effectively established within the time frame 2007-2013.

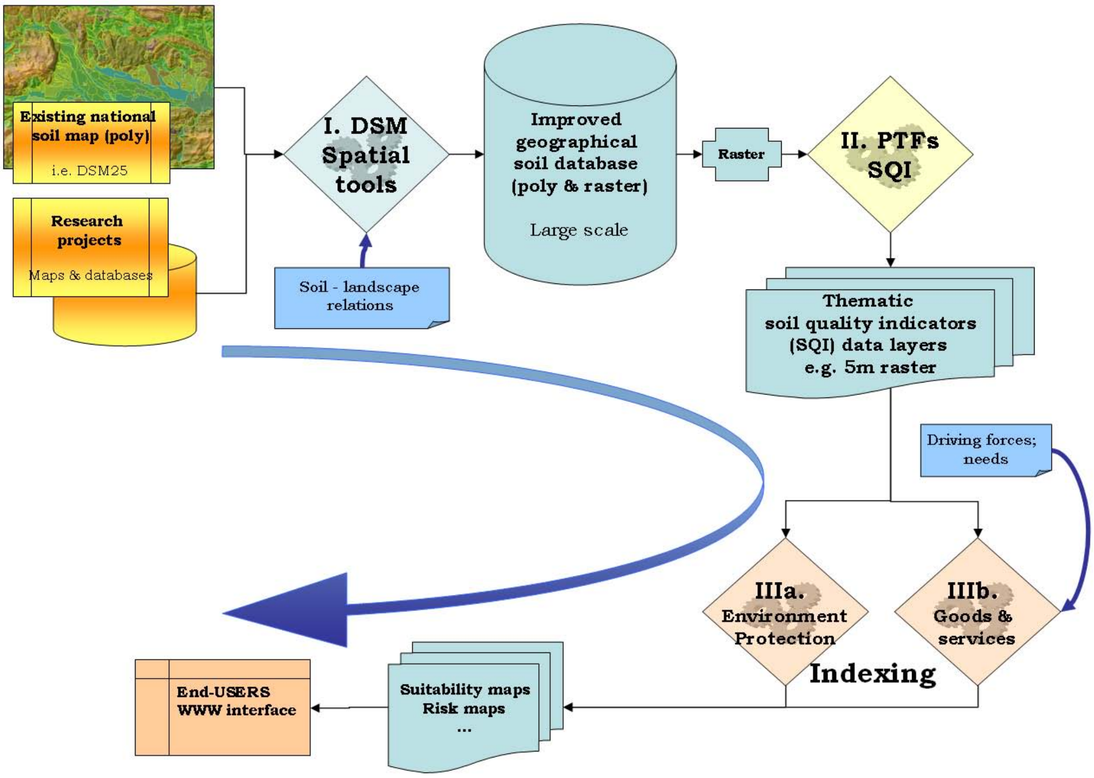


**Fig. XVI.2. The workflow and the intermediate steps in the preparation of the end-user oriented soil databases.**

### *XVI.5.7 The empirical knowledge based DSM method for DSM25 geometry improvement*

The expert knowledge based DSM method for the improvement of the DSM25 geometry was developed within the Javorniki test case area as a part of the SPIN research project (Bock et al., 2005). The main information used in the model were the DSM25, the point soil profile data with descriptions of soil horizons and standard soil analytical data, DEM at 25 m resolution, precipitation data, the 1:100,000 lithological map, and the 1:5,000 land use map. The panchromatic enhanced IKONOS, the Landsat TM (1996, bands 453 composite), the DOF5 images and the 1:10,000 vector soil map of the area were used for the visual control of the model results.

Within the test area the DSM25 was composed of 36 different SMUs and 49 different STUs. For each STU the soil properties were verified and supplemented and the attributes related to the geomorphologic features/landforms of the STU were defined. The probability of the STU appearance for each of 11 landforms present in the area was determined using empirical knowledge. MS ACCESS database was used to process the attributes and to derive GIS model parameters. The model for the spatial prediction of certain STUs within SMUs has been elaborated in the ArcInfo GRID module using the AML language. The result of the modelling is a predicted soil map in a grid format where the SMU polygons are disaggregated to the grid cells indicating the spatial position of the individual STUs (Fig. XVI.3). The spatial resolution of the grid cell is 25 m and the geometry of the resulting raster soil map is improved in comparison to the original vector DSM25 polygons (Fig. XVI.4).

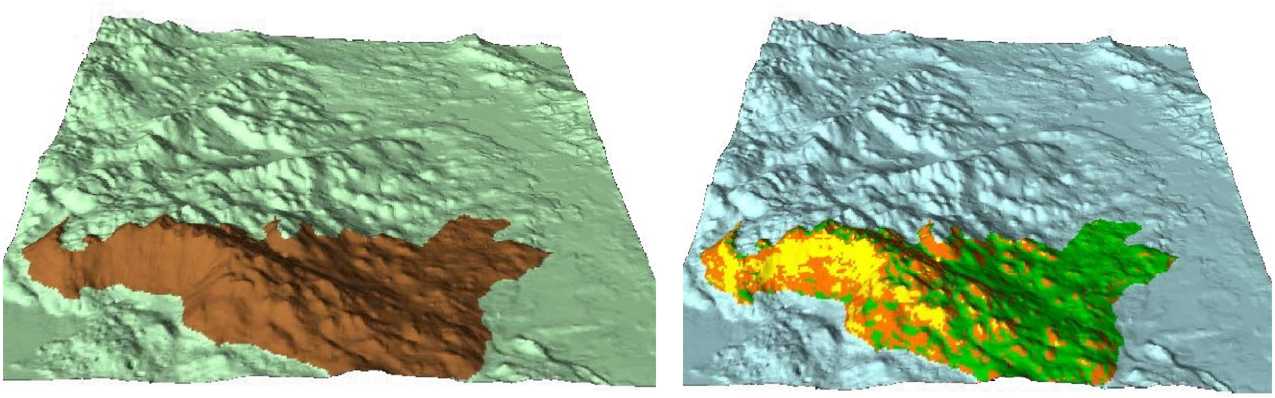

**Fig. XVI.3: An example of the DSM25 disaggregation. Original DSM25 SMU polygon (left). Predicted locations of three STUs. (right).**

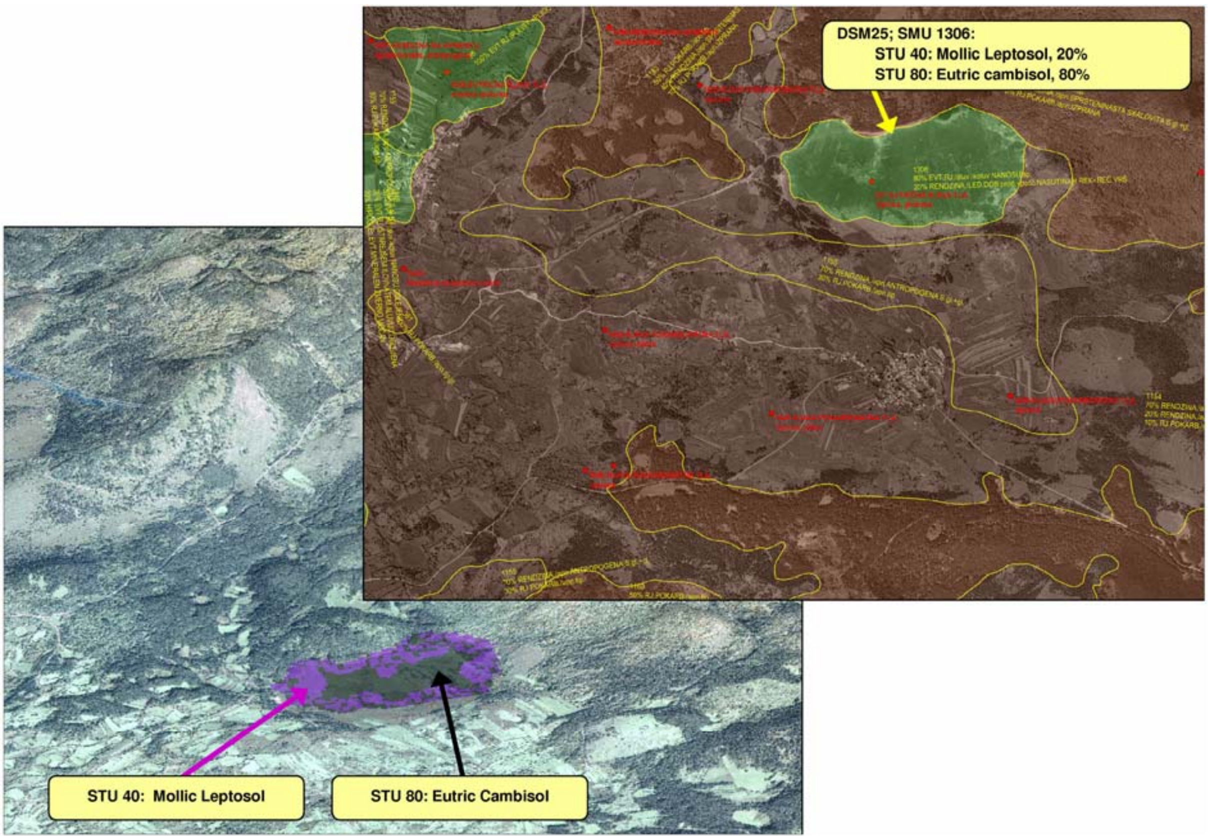


**Fig. XVI.4. Disaggregation of a SMU to determine the spatial location of the STU using the expert knowledge approach.**

The raster soil map grid was later used to derive thematic maps of selected soil properties (e.g. organic matter content in the A horizon, predominant texture class of A and B horizons, the pH of the A and B horizons, average soil depth, rooting depth, etc.) The separate soil properties layers were subsequently used in relation to the NATURA 2000 to predict the locations of three rare protected habitats within the test area (Langanke et al., 2005). The method will be further developed.

### *XVI.5.8 Research activities*

The most relevant research activities required to improve/elaborate soil and soil related information for local scale use as foreseen by the AIS are:

- **The development of the DSM methods** for the elaboration of large scale information encompass:
  - The further development of the empirical knowledge based DSM method for the improvement of the existing vector based soil maps
  - The introduction of the geostatistical and fuzzy-logic based DSM methods and their adaptation of the territory of Slovenia
  - The combination and interaction of the above mentioned DSM methods
- **The development and the adaptation of pedotransfer functions**
- **The introduction of large scale soil information** for the adaptation of existing agricultural practices to spatial planning procedures and environmental protection purposes.

Selected aspects are already carried out within recent AIS research activities. As foreseen, they will be intensified through cooperation with other research institutions in national and international research projects.

## XVI.6 Conclusions

The soil protection and management actions as announced by the newest *European Soil Thematic Strategy* and the *Proposal for a Soil Protection Directive of the European Parliament and the Council* will require soil and land information adapted to local-scale needs. The soil information in Slovenia should be improved in order to be successfully and satisfactorily used for local scale soil protection and environmental management. The national soil quality indicator set has to be designed, pedotransfer functions developed, and soil quality monitoring systems established. The improved soil information system has to be designed and the interpreted soil information disseminated to end-user groups.

The DSM techniques can enable the updating and improvement of existing soil databases more efficiently in a shorter time and at a lower cost, and represent the only reasonable alternative to expensive and time-consuming field soil mapping. Local scale soil information can be elaborated using DSM methods. The development of DSM methods for the downscaling and the improvement of soil information is an important objective of the soil research community. DSM modelling based on empirical knowledge has been shown to be practicable. The model has to be further developed by adding additional *scorpan* layers-information and combined with geostatistical and data-mining based DSM techniques. The DSM method used in an area should be adapted to the local specifics (i.e. the topography, soils, land uses, data availability, empirical knowledge). Thus it is important that DSM models are developed within national soil research institutions.

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- *The Ministry of Defence, for financing the project within which a significant amount of new soil profile data will be collected and will contribute, besides to military purposes, also to the improvement of the general purpose soil dataset of Slovenia.*

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# XVII. GIS-aided agro-ecological zoning of former Yugoslav Republic of Macedonia

Dusko Mukaetov[1], Ordan Cukaliev[2] Tijana Sekuloska[1] and Ivan Mincev[2]

1 Institute of Agricutlure,
bul. Aleksandar Makedoski b.b., 1000 Skopje, Macedonia
Tel.: + 389 2230 910 ext. 305; Fax: + 389 23114 283
d.mukaetov@zeminst.edu.mk; tijanasekuloska@gmail.com

2 Faculty of Agricultural Sciences and Food,
bul. Aleksandar Makedonski b.b., 1000 Skopje, Macedonia
Tel.: + 389 23115 277;
Ordan.cukaliev@fasf.ukim.edu.mk; i_mincev@yahoo.com

**Summary**

*Sustainable agricultural development requires a systematic attempt towards the planning of land use activities in the most suitable way. Agro-ecological zoning (AEZ) is one of the most significant approaches for agricultural developmental planning because survival and failure of particular land use or farming system in a given region heavily relies on careful assessment of agro-climatic resources. This approach is used to categorize agro-climatically uniform geographical areas for agricultural developmental planning and other interventions. Modern tools such as satellite remote sensing and Geographical Information System (GIS) have been providing newer dimensions to effectively monitor and manage land resources in an integrated way for agro-ecological characterization. This paper tries to demonstrate incorporation of new tools to extend applicability of Agro-ecological zoning in Republic of Macedonia. For the purpose of this study long term (30 years) monthly maximum and minimum temperatures has been collected. Digital elevation model with 80 m grid in a national Gauss Kruger projection has been employed. The empirical relations thus developed were used to utilize inherent spatial quality of digital elevation model in GIS environment for depicting spatial variation in normal annual mean temperatures as well as annual rainfall condition over the whole country, which was further on used to compute the spatial PET and moisture index (MI). With overlaying of the moisture index (MI) map and reclassified CORINE land cover an output map indicating the Agro-climatic zones was created. Agro-edaphic zoning for this study was done by incorporating several factor such as: soil texture map to which four textural classes were assigned to each soil type respectfully, terrain parameter as slope map derived from the Digital elevation model (DEM) classified in five classes (Lambert, J.J. et al 2002) and soil map that has been drafted in digital format in a scale 1:100 000. All agro-edaphic layers and climatic layer described above were integrated or overlaid to derive different unique agro-ecological cells. These agro-ecological cells were further combined to arrive at agro-ecological zones based on their potential to support agriculture and different vegetation patterns.*

## XVII.1 Introduction

Sustainable agricultural development requires a systematic effort towards the planning of land use activities in the most appropriate way, apart from several other institutional and policy programme initiatives. **Agro-ecological zoning** (AEZ) is one of the most important bases for agricultural developmental planning because survival and failure of particular land use or farming system in a given region heavily relies on careful assessment of agro-climatic resources. The approach is used to categorize agro climatically uniform geographical areas for agricultural developmental planning and other interventions. A framework of agro-ecological zoning describing concepts, methods and procedures was conceptualized for the first time by FAO (1976).

Agro-ecological zoning refers to the division of an area of land into land resource mapping units, having unique combination of landform, soil and climatic characteristics and or land cover having a specific range of potentials and constraints for land use (FAO, 1996). The particular parameters used in the definition put attention on the climatic and edaphic requirements of crop and on the management systems under which the crops are grown. Each zone has a similar combination of constraints and potentials for land use and serves as a focus for the targeting of recommendations designed to improve the existing land use situation, either by increasing production or by limiting land degradation. An output of AEZ studies includes maps showing agro-ecological zones and land suitability, quantitative estimates of potential crop yields and production. Such information provides the basis for advanced applications such as land degradation assessment, livestock productivity modeling, population support capacity assessment and land use optimization modeling.

### *XVII.1.1 Definitions*

Agro-Ecological Zoning (AEZ) refers to the division of an area of land into smaller units, which have similar characteristics related to land suitability potential production and environmental impact. Agro-Ecological Zone is a land resource mapping unit, having a unique combination of land form, soil and climatic characteristics and/or land cover having a specific range of potentials and constraints for land use (FAO, 1996). Agro-Ecological Cell (AEC) is defined by a unique combination of land form, soil and climatic characteristics.

### *XVII.1.2 New tools for AEZ*

Modern tools such as satellite remote sensing and GIS have been providing newer dimensions to effectively monitor and manage natural resources. It has been well conceived that remote sensing and GIS have great role to play in agro-ecological zoning for sustainable development applications due to multi-stage character of agro-ecological zoning. In the past several approaches of AEZ involved manual integration of agro-climatic and other natural resource data.

As a result, large amount of agro-ecological data could not be handled easily and aggregation was required at an early stage in the analysis. This led to loss of information on spatial variability. On the other hand, GIS technology is very useful for automated logical integration of bio-climate, terrain and soil resource inventory information (Patel et al., 2000). The system is capable of containing all data required to solve resource management problems. Topographic maps, land resource map and contour map having physiographic, geographic and bio-climatic information forms primary input for GIS for agroe-cological zoning activities. For this study the following set of information has been compiled in digital format which will serve as a input for further GIS analysis toward definition of the agro-ecological zones:

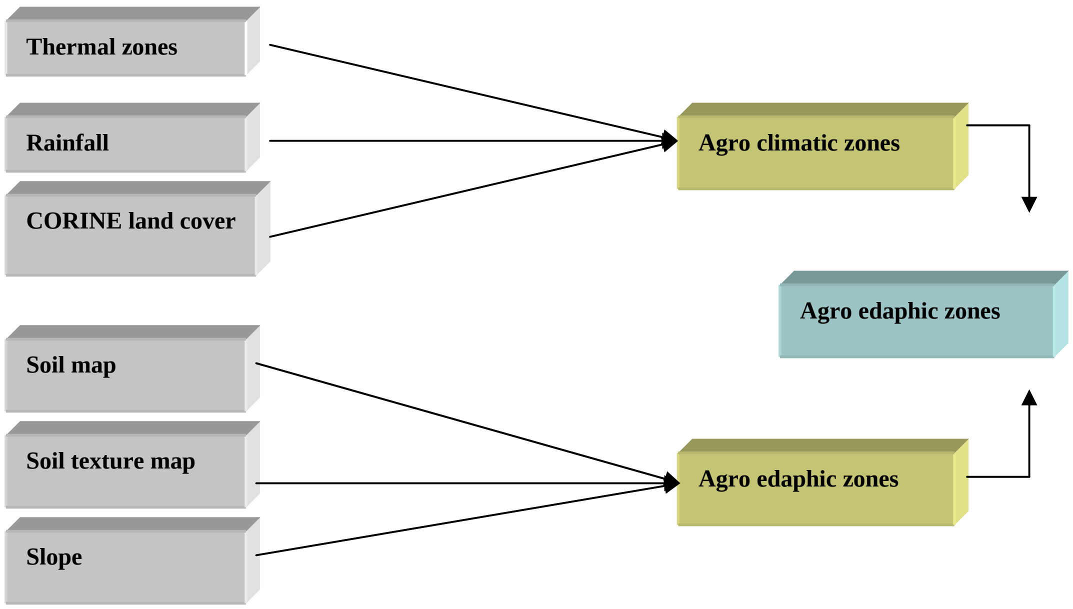


**Fig. XVII.1. Inputs and outputs for demarcation of the agroecological zones.**

### *XVII.1.3 Dataset*

The dataset comprised:

- Meteorological data for a thirty year period for temperature and rainfall from 34 meteostations in Macedonia and their coordinates.
- DEM with spatial resolution of 80 m
- CORINE land cover
- Soil maps in hard copy which were latter digitized

## XVII.2 Methodology and results

For the purposes of the Agro-ecological zoning of the study area, the following GIS analysis was carried out by the experts of the GIS department of the Institute of Agriculture, Faculty of agricultural sciences and food and State authority for hydrometeorogical works:

- Creation of agro climatic zones
- Agro-edaphic zoning
- Delineation of agro-ecological zones

### *XVII.2.1 Creation of agro climatic zones*

Long term (30 years) monthly maximum and minimum temperatures for the period 1971 to 2000 has been collected from 34 meteorological stations. Digital elevation model with 80 m grid size has be provided in a national Gauss Kruger projection, by Ministry of Environment and Physical planning. Long term annual averages of annual mean temperatures and active temperatures of all (34) meteorological stations for both periods were regressed against corresponding elevation. A good agreement has been observed between these two parameters ($R^2$=0.92) for the period 1971-2000, respectively. Similarly long term average annual rainfall recorded at the same meteorological stations were regressed against elevation for developing rainfall–elevation relationship ($R^2$=0.75) representing the region under study. The empirical relations thus developed were used to utilize inherent spatial quality of digital elevation model in GIS environment for depicting spatial variation in normal annual mean temperatures as well as annual rainfall condition over the whole country.

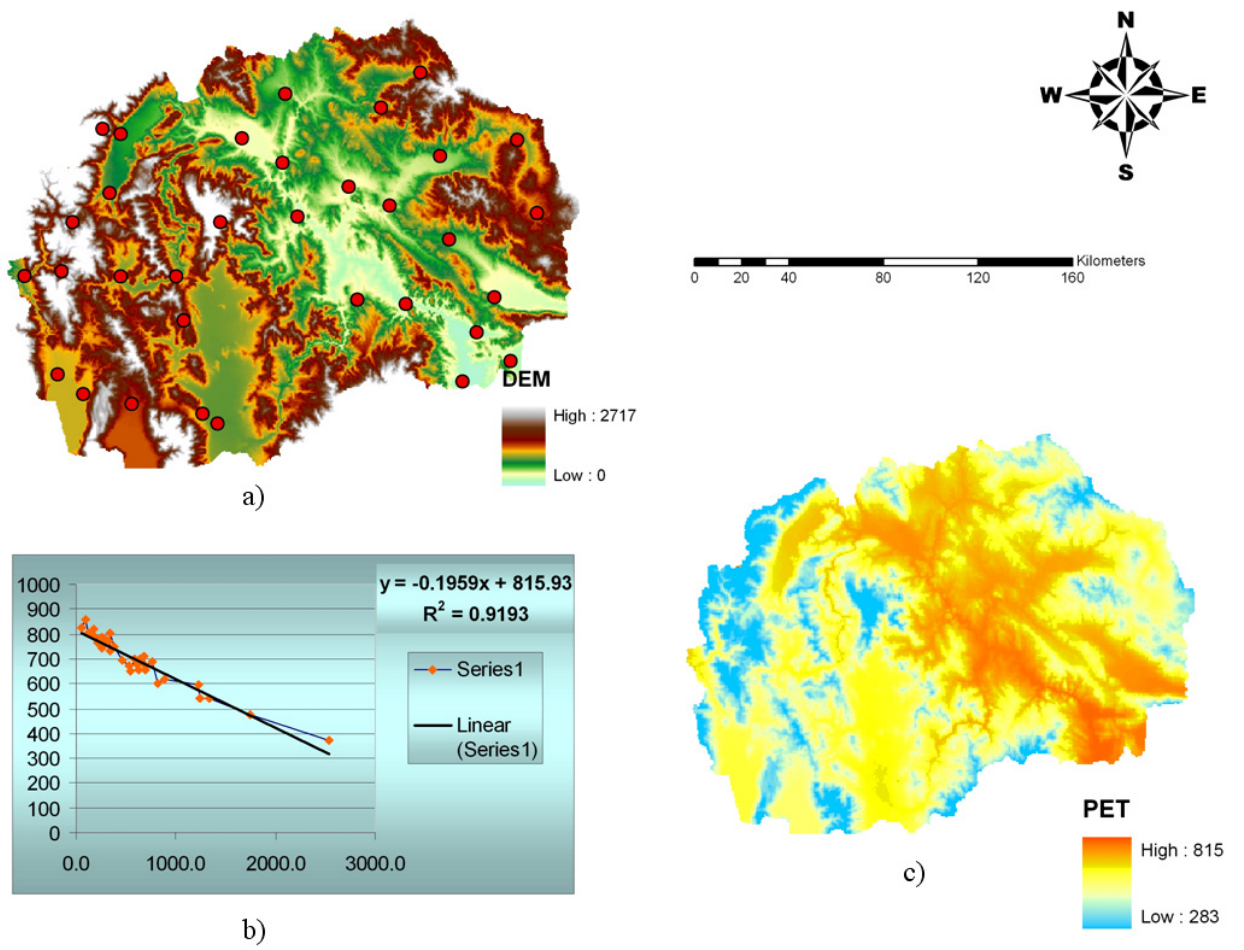


**Fig. XVII.2. (a) DEM and distribution of the meteorological stations; (b) regression analysis PET vs. elevation and (c) spatial distribution of PET.**

In the creation of moisture regime database, data for rainfall and temperature were used taken from 34 meteorological stations over the period of 30 years. From available data the monthly spatial distribution of mean temperatures were used for computation of spatial potential evapo-transpiration (PET) based on equation developed by Thornthwaite (1948):

$$\mathrm{PET} = 1.6 \cdot \left[ \frac{10 \cdot T_{Ijk}}{I_{jk}} \right]^{ajk} \tag{1}$$

where

$$I_{jk} = \sum_{i=Jan}^{Dec} \left( \frac{T_{Ijk}}{5} \right)^{1.514} \tag{2}$$

T = Mean air temperature ($^{o}$C)
i = Month of a year (i = Jan, Feb,…,Dec)
j = Pixel value of i th row
k = Pixel value of j th column

$$a_{jk} = 67.5 \cdot 10^{-8} \cdot \left(I_{jk}\right)^{3} - 7.71 \cdot 10^{-5} \cdot \left(I_{jk}\right)^{2} + 0.01792 \cdot \left(I_{jk}\right) + 0.4923 \tag{3}$$

These monthly potential evapo-transpiration were summed over twelve months in a year to obtain spatial distribution of annual PET for each meteorological station in order to be used in computation of moisture index (MI). After that the regression analysis was performed and it was noted that a regression with high coefficient of determination exists when PET is plotted against altitude. The gradient received was further one assigned to the existing DEM with 80 m resolution. As an output we receive a PET map for whole territory with significant degree of accuracy as shown in Fig. XVII.2.

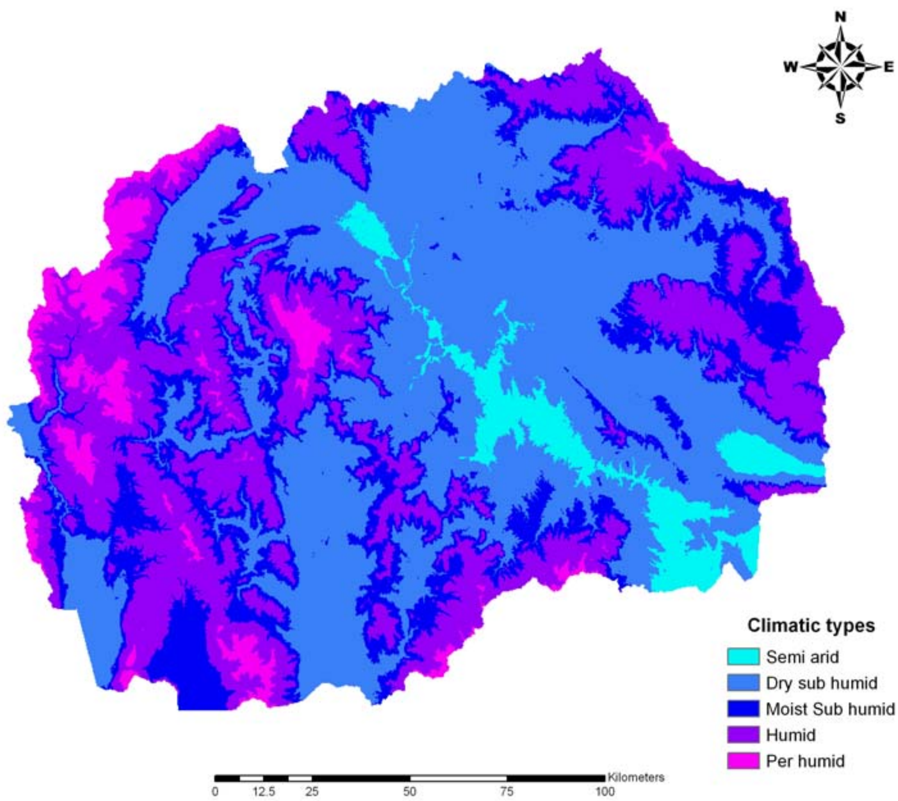


**Fig. XVII.3. Spatial distribution of different climatic types.**

The derived PET grid and rainfall grid were further used for calculation of Moisture index (MI) according to the equation established by Thornwaite and Mather (1955) which represent water accessibility for crop production and hence it is very important for classification of the agro-climatic zones:

$$MI = \frac{P - PET}{PET} \ \% \qquad (4)$$

where

MI = Moisture Index
P = Rainfall (mm)
PET = Potential Evapo-transpiration (mm)

The rainfall factor used in the equation above was derived by plotting the rainfall data versus elevation. Rainfall time series collected on climatic stations create the data source for derivation of regression equation representing the dependence of temperature on elevation, in our case high coefficient of determination equal to 0.75 was found. Using this equation, the DEM data can be used to map the rainfall covering the whole territory. The information on moisture index is essential for the biotic environment and has been used to classify the climatic types. In order derive homogeneous zones; the moisture index of the various climatic types was classified as shown in Table XVII.1. The map of climatic types is given in Fig. XVII.3.

**Table XVII.1. Look up table for classification of the climatic types according to the values of the moisture index.**

| *Climatic type* | *Moisture index* |
|---|---|
| Semi arid | -66.7 to -33.3 |
| Dry sub-humid | -33.3 to 0 |
| Moist sub-humid | 0 to 20 |
| Humid | 20 to 100 |
| Per-humid | >100 |

Land use/land cover information was derived from CORINE land cover project at scale 1:100,000. The CORINE has three levels of classification with different number of classes. For the purpose of this study the second level with originally 15 classes was used. The classes were further on, generalised to 6 classes on the basis of their response to climatic change, as follows: *arable land, forest and semi natural areas, heterogeneous agricultural areas*, *pastures*, *permanent crops*, *non-productive lands*. An output map indicating the agro climatic zones was created by finally overlaying of the moisture index (MI) map and reclassified CORINE land cover.

### *XVII.2.2 Agro-edaphic zoning*

Agro-edaphic zoning for this study was done by incorporating several factor: soil type map to which four textural classes (Loam, Loamy clay, Clay Loam and sandy Loam) were assigned respectively and slope map was derived from the Digital elevation model (DEM) and classified into five classes (0-2%, 2-8%, 8-15%, 15-25% and more than 25%).

Soil map has been drafted in digital format at a scale 1:100,000. It has been produced by using the existing hard copy map at a scale 1:250,000 and numerous existing studies and manuscripts of different investigations and monitoring. It should be noted that this map represents only a graphical presentation of the spatial distribution of different soil types and soil associations and does not contains auxiliary data for the soil chemical and physical properties. Unavailability of a more detailed soil map of Macedonia in digital format with spatial and attribute datasets represents a serious shortage for this and similar analysis. For this reason compilation of this document out of the existing hard copy soil map in a scale 1:50,000 and corresponding alpha-numerical data is an urgent future activity.

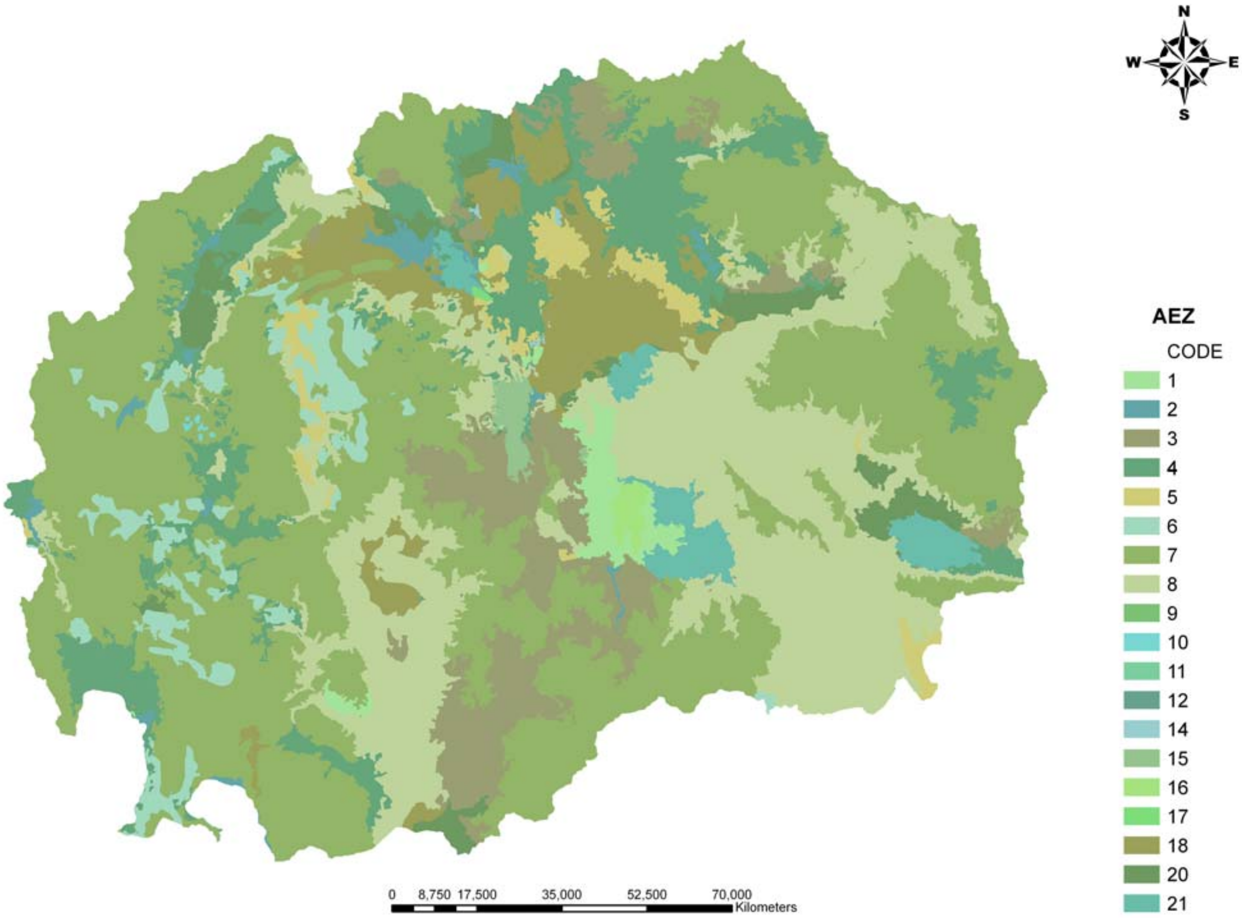


**Fig. XVII.4. Spatial distribution of agro ecological zones. See the explanation of classes in Table XVII.2.**

During the preparation of the soil map for this study, 27 soil associations and 22 soil types were delineated. For the purposes of the agro ecological zoning according to the FAO Soils Bulletin 73 (1996), guidelines additional three GIS layers representing texture classes of each soil type and soil association, topology and slope have been prepared. Due to the unavailability of an attributive dataset of the soil map, the texture classification of the various soil types and association has been prepared on the base of the existing large data set with a vast number of soil profiles for various soil types in the Monograph Soils of Macedonia Vol. I-IV (Filipovski, G. 1995, 96, 97, 99, 2001). Classification of the topology and slope into several classes has been prepared according to the **Soil Geographical Database for Eurasia & The Mediterranean**: Instructions Guide (Lambert, J.J. (2002). Due to a lack of reliable data a classification of different soil types according to the soil depth has not been prepared.

After overlaying of all GIS layers, due to a numerous soil types and associations a huge number of Agro ecological cells (AEC) were received. For this reason, it was decided to overlay only the layers indicating the texture class and slope in order to calculate an output map indicating the agro-edaphic zones. All agro-edaphic layers and climatic layer described above were integrated or overlaid to derive different unique agro-ecological cells. These agro-ecological cells were further combined to arrive at agro-ecological zones based on their potential to support agriculture and different vegetation patterns.

### *XVII.2.3 Delineation of agro-ecological zones*

Agro-climatic zones are of principal importance for defining or for demarcation of agro-ecological zoning for sustainable use of land resources. The fundamental elements in demarcating an agro-climatic zone are bioclimates based on thermal regimes; moisture regime and land cover changeability. Nineteenth different agro-climatic zones were delineated by GIS aided integration of moisture regimes and agro-edaphic map layers (Fig. XVII.4). In Table XVII.2, results of the Agro-ecological zoning representing the spatial distribution and extent of the derived agro ecological zones are given.

**Table XVII.2. Spatial extent of the agro ecological zones.**

| *CODE* | *Area (km²)* | *Percentage* | *AEZ* |
|---|---|---|---|
| **1** | 325,4285174 | 1,3030 | Permanent crops |
| **2** | 218,5643417 | 0,8751 | Non productive lands |
| **3** | 1888,008558 | 7,5597 | Pastures |
| **4** | 2481,246705 | 9,9351 | Heterogenous agricultural areas |
| **5** | 520,9780953 | 2,0860 | Forest and natural vegetation located on slopes >15%, on soil types with LC and CL texture in semi arid and dry sub humid climatic type |
| **6** | 845,3732932 | 3,3849 | Forest and natural vegetation located on slopes >15%, on soil types with LC and CL texture in moist sub humid, humid and per humid climatic type |
| **7** | 10498,26808 | 42,0358 | Forest and natural vegetation located on slopes >15%, on soil types with SL and L texture in moist sub humid, humid and per humid climatic type |
| **8** | 5357,789221 | 21,4530 | Forest and natural vegetation located on slopes >15%, on soil types with SL and L texture in semi arid and dry sub humid climatic type |
| **9** | 0,376562494 | 0,0015 | Forest and natural vegetation located on slopes <15%, on soil types with SL and L texture in semi arid and dry sub humid climatic type |
| **10** | 11,11641594 | 0,0445 | Forest and natural vegetation located on slopes <15%, on soil types with SL and L texture in moist sub humid, humid and per humid climatic type |
| **11** | 0,056601541 | 0,0002 | Forest and natural vegetation located on slopes <15%, on soil types with LC and CL texture in moist sub humid, humid and per humid climatic type |
| **12** | 0,379999974 | 0,0015 | Forest and natural vegetation located on slopes <15%, on soil types with LC and CL texture in semi arid and dry sub humid climatic type on soil types with LC and CL texture |
| **14** | 11,78118477 | 0,0472 | Arable land located on slope >15 on soil types with LC and CL texture and dry sub humid, moist sub humid, humid and per humid climatic type |
| **15** | 117,2200576 | 0,4694 | Arable land located on slope >15 on soil types withSL and L texture and dry sub humid, moist sub humid, humid and per humid climatic type |
| **16** | 77,70979395 | 0,3112 | Arable land located on slope >15 on soil types withSL and L texture and semi arid climatic type |
| **17** | 8,168133914 | 0,0327 | Arable land located on slope <15 on soil types with LC and CL texture and semi arid climatic type moist humid, dry sub humid, humid and per humid climatic type |
| **18** | 1424,103566 | 5,7022 | Arable land located on slope <15 on soil types with LC and CL texture and moist sub humid, dry sub humid, humid and per humid climatic type |
| **20** | 677,1833883 | 2,7115 | Arable land located on slope <15 on soil types with SL and L texture and moist sub humid, dry sub humid, humid and per humid climatic type |
| **21** | **510,847095** | 2,0455 | Arable land located on slope <15 on soil types with SL and L texture and moist sub humid, dry sub humid, humid and semi arid climatic type |

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Abstract

This report is an output of the JRC's European Soil Bureau Network workshop that was held at the Faculty of Agriculture in Zagreb, Croatia in period from 28-30 of September 2006. The objective of this workshop was to gather key players in the development and/or implementation of soil protection policy, soil survey, soil monitoring and soil information systems and discuss further strengthening of collaborations between the countries of south-eastern Europe and JRC. This report gives an overview of the activities considering the organization of the soil data and soil protection policies in the countries of south-eastern Europe: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Macedonia, Serbia and Slovenia. In addition, several chapters were contributed by Digital Soil Mapping groups from the region. The methodology presented sets a basis for further work on production of soil geoinformation systems, dissemination of soil information and its utilization for decision making, both at regional, national and European levels.

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